VOLUME VIII. NUMBER 5

# THE JOURNAL OF THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES



PUBLISHED BI-MONTHLY

SEPTEMBER-OCTOBER, 1914

PRINTED FOR THE SOCIETY
TORONTO: 198 COLLEGE ST.

FOREIGN AGENTS: WILLIAM WESLEY & SON,
28 ESSEX ST., STRAND, LONDON.

# THE JOURNAL

## OF THE

# ROYAL ASTRONOMICAL SOCIETY OF CANADA

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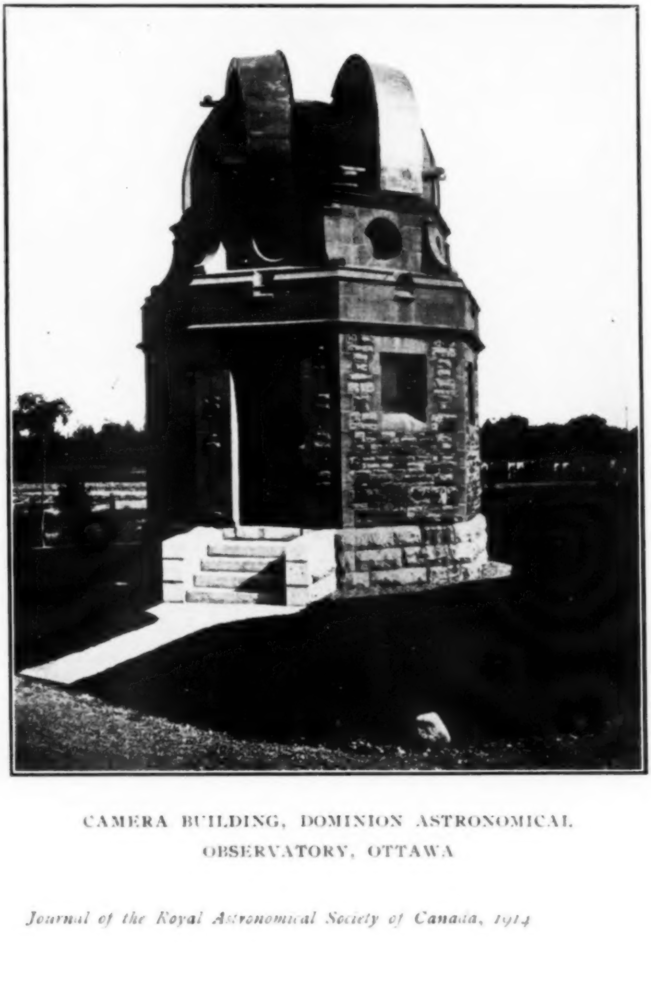
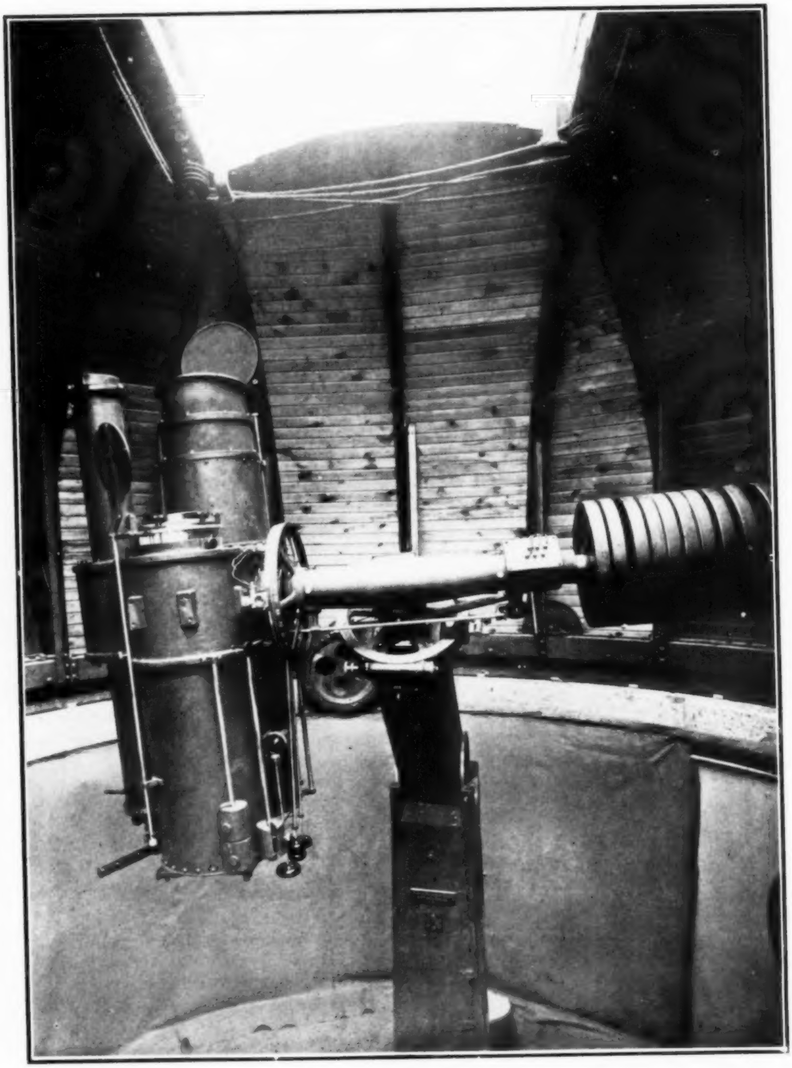
PLATE VI.



CAMERA BUILDING, DOMINION ASTRONOMICAL OBSERVATORY, OTTAWA

PLATE VII.



PHOTOGRAPHIC TELESCOPE,
DOMINION ASTRONOMICAL OBSERVATORY, OTTAWA
Mounted June-July, 1914

*Journal of the Royal Astronomical Society of Canada, 1914*

# THE JOURNAL
## OF THE
## ROYAL ASTRONOMICAL SOCIETY
## OF CANADA

VOL. VIII. SEPTEMBER-OCTOBER, 1914. No. 5

## THE NEW PHOTOGRAPHIC TELESCOPE OF THE DOMINION OBSERVATORY.

By R. M. Motherwell.

THE original equipment of the Astrophysical Branch of the Dominion Observatory included an 8-inch doublet attached to the 15-inch equatorial. This arrangement was found unsatisfactory as the doublet could not be used without interfering with other work and the equatorial mounting was not suitable for carrying an exposure through the meridian. It was therefore decided to mount the doublet separately.

The contract was given to the John A. Brashear Co. and the instrument complete was delivered in July, 1912, but the building (see Plate VI.), was not completed until the present summer.

The instrument, as now mounted, consists of an 8-inch doublet with focal length of forty-one inches, a 6-inch doublet with focal length of thirty inches, a Zeiss-Tessar lens of 3·3 inches aperture and 11·8 inches focal length, a guiding telescope of 4·5 inches aperture and 52·5 inches focal length and two prisms of 15° and 25° which can be attached, individually or combined, to the 8-inch.

(Plate VII.) shows the instrument with the 15° prism attached. It also shows the design of the pier to permit of continuous exposure through the meridian at any declination. Provision is made for lowering or raising the pier-head by means of a worm in order that the instrument may be used in any latitude. The end of the worm used for this purpose is visible just above the name-plate.

The building is octagonal, surmounted by a dome fourteen feet in diameter. The lower part of the building is divided into two parts, one containing the spiral stairway from which access is had to the dome through a sectional trap-door, and the other is used as a dark-room for loading plates.

Dominion Observatory,
Ottawa, Canada.

# THE SOLAR ROTATION IN 1913

BY H. H. PLASKETT

IN the study of the solar rotation by spectroscopic methods there are three main problems for research :—

(*a*) The accurate determination of the velocity at various latitudes, and the derivation of a formula connecting the variation of velocity with that of latitude,

(*b*) A study of the velocities given by different lines to determine whether the absolute rate of rotation varies with different elements, and

(*c*) A discussion of the errors involved.

It will be under three such heads as this that the "Solar Rotation in 1913" will be treated.

The plates on which this discussion is based were taken in the λ5600 region during the month of June, 1913, by R. E. DeLury and the writer. The apparatus for taking the plates has been described elsewhere.* Some thirty-one plates were made, on each of which there were nine rotation spectra, one at each of the latitudes, 0°, 15°, 30°, 45°, 60°, 75°, 80°, 85° and 90°.

In these spectra displacements were measured for the twelve lines in Table I. Two settings were made on the line in the centre strip, and one setting on each of the lines in the outside strip. The image of the plate was then inverted by means of a reversing eye-piece, and the settings made as before. After the displacements had been determined, they were multiplied by the

* "The Solar Rotation in 1911," J. S. Plaskett and R. E. DeLury, *Astrophysical Journal*, Vol. XXXVII., No. 2.

TABLE I.—LINES IN λ5600 REGION

| No. | Wave-Length | Element | Intensity | Velocity Constant | No. | Wave-Length | Element | Intensity | Velocity Constant |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 5544·157 | Fe | 2 | 19·118 | 7 | 5582·198 | Ca | 4 | 18·899 |
| 2 | 5560·434 | Fe | 2 | 19·024 | 8 | 5590·343 | Ca | 3 | 18·852 |
| 3 | 5562·933 | Fe | 2 | 19·010 | 9 | 5601·505 | Ca | 3 | 18·788 |
| 4 | 5569·848 | Fe | 6 | 18·970 | 10 | 5624·769 | Fe V | 3 | 18·653 |
| 5 | 5576·320 | Fe | 4 | 18·933 | 11 | 5638·488 | Fe | 3 | 18·575 |
| 6 | 5578·946 | Ni | 1 | 18·919 | 12 | 5658·097 | V | 2 | 18·461 |

velocity constant in Table I., and the probable error for a single line was computed. All spectra showing a greater probable error than ± 0·050 km. per second were re-measured, and the value of the displacement, showing the smaller probable error, was used in the final result. The final reduction was made by Method I.*

SECTION I.—VALUES OF VELOCITY

In Table II. will be found a summary of the measured and corrected values of the velocity for twenty plates with eight latitudes on each. In addition to this, eleven other plates were measured in the equatorial region. Lack of space forbids giving a summary of their measures. Suffice it to say that the thirty-one plates at the equator gave the following mean values :—

Mean measured velocity .... 1·808 km. per sec.
Mean corrected velocity .... 1·991 km. per sec.
Mean angular velocity .... 14°·14 per day.
Probable error, single plate .. ± 0·017 km. per sec.

Using all the lines on all the plates we find a

Mean probable error, single line.... ± 0·039.

Also from a comparison of the velocities of all the plates at the same latitude, and all the latitudes we have

Mean probable error, single plate .... ± 0·025.

* "The Solar Rotation," J. S. Plaskett and R. E. DeLury, *Transactions of the Royal Society of Canada*, 1912, Section 3, p. 7.

Faye's formulæ were used for the variation of velocity with latitude. They are of the form :—

$$(a + b \cos^2 \phi) \cos \phi = V$$
$$a' + b' \cos^2 \phi = \xi.$$

where $\phi$ is the latitude, $V$ the linear and $\xi$ the angular velocity, and $a$, $b$, $a'$, $b'$, are constants whose values have to be determined.

These constants were determined by the method of least squares, each value being properly weighted.

The following were the values determined for these constants :—

$$(1{\cdot}441 + 0{\cdot}537 \cos^2 \phi) \cos \phi = V$$
$$10^\circ{\cdot}23 + 3^\circ{\cdot}81 \cos^2 \phi = \xi$$

TABLE II.—SUMMARY OF MEASURES

| Plate | Date G.M.T. 1913 | Mean Lat. = 0° 0′ Measured Vel. | Mean Lat. = 0° 0′ Corrected Vel. | Mean Lat. = 15° 0′ Measured Vel. | Mean Lat. = 15° 0′ Corrected Vel. | Mean Lat. = 30° 0′ Measured Vel. | Mean Lat. = 30° 0′ Corrected Vel. | Mean Lat. = 45° 0′ Measured Vel. | Mean Lat. = 45° 0′ Corrected Vel. |
|---|---|---|---|---|---|---|---|---|---|
| | d h | | | | | | | | |
| L 979 | June 6 19·28 | 1·802 | 1·987 | 1·646 | 1·824 | 1·470 | 1·641 | 1·113 | 1·236 |
| 985 | 9 17·48 | 1·763 | 1·944 | 1·653 | 1·826 | 1·435 | 1·591 | 1·119 | 1·241 |
| 986 | 9 17·88 | 1·774 | 1·955 | 1·665 | 1·837 | 1·478 | 1·636 | 1·191 | 1·316 |
| 987 | 10 16·72 | 1·794 | 1·975 | 1·649 | 1·821 | 1·454 | 1·611 | 1·067 | 1·189 |
| 988 | 10 17·03 | 1·807 | 1·990 | 1·663 | 1·836 | 1·458 | 1·614 | 1·087 | 1·209 |
| 989 | 10 17·70 | 1·819 | 2·001 | 1·597 | 1·768 | 1·417 | 1·572 | 1·047 | 1·169 |
| 990 | 10 17·97 | 1·816 | 1·999 | 1·721 | 1·896 | 1·436 | 1·594 | 1·081 | 1·204 |
| 992 | 10 18·60 | 1·845 | 2·028 | 1·657 | 1·830 | 1·424 | 1·581 | 1·053 | 1·174 |
| 994 | 10 19·20 | 1·872 | 2·055 | 1·722 | 1·896 | 1·432 | 1·589 | 1·128 | 1·251 |
| 996 | 10 19·78 | 1·833 | 2·016 | 1·660 | 1·832 | 1·462 | 1·619 | 1·107 | 1·229 |
| 998 | 10 20·38 | 1·794 | 1·975 | 1·720 | 1·893 | 1·482 | 1·636 | 1·150 | 1·274 |
| 1000 | 10 21·00 | 1·803 | 1·985 | 1·670 | 1·844 | 1·474 | 1·633 | 1·129 | 1·251 |
| 1003 | 13 17·22 | 1·806 | 1·992 | 1·668 | 1·844 | 1·489 | 1·649 | 1·146 | 1·274 |
| 1005 | 13 18·12 | 1·776 | 1·961 | 1·642 | 1·817 | 1·438 | 1·596 | 1·085 | 1·209 |
| 1007 | 13 18·65 | 1·770 | 1·954 | 1·645 | 1·821 | 1·492 | 1·704 | 1·060 | 1·184 |
| 1011 | 15 17·35 | 1·820 | 2·002 | 1·656 | 1·829 | 1·392 | 1·546 | 1·090 | 1·214 |
| 1013 | 15 18·23 | 1·778 | 1·958 | 1·646 | 1·819 | 1·451 | 1·606 | 1·068 | 1·191 |
| 1015 | 15 18·85 | 1·818 | 1·997 | 1·638 | 1·809 | 1·378 | 1·532 | 1·111 | 1·234 |
| 1017 | 15 19·55 | 1·853 | 2·033 | 1·649 | 1·819 | 1·422 | 1·576 | 1·102 | 1·225 |
| 1018 | 15 19·78 | 1·790 | 1·969 | 1·640 | 1·810 | 1·412 | 1·566 | 1·084 | 1·206 |
| Means (Linear) | | 1·807 | 1·989 | 1·660 | 1·834 | 1·445 | 1·605 | 1·161 | 1·224 |
| Means (Angular) | | | 14°·12 | | 13°·48 | | 13°·16 | | 12°·20 |
| Prob. Error, Single Plate | | ± 0·019 | | ± 0·020 | | ± 0·028 | | ± 0·025 | |

TABLE II.—SUMMARY OF MEASURES.—(*Continued*)

| Plate | Date G.M.T. 1913 | Mean Lat. = 60° | | Mean Lat. = 74° 58′ | | Mean Lat. = 79° 58′ | | Mean Lat. = 84° 55′ | |
|---|---|---|---|---|---|---|---|---|---|
| | | Measured Vel. | Corrected Vel. | Measured Vel. | Corrected Vel. | Measured Vel. | Corrected Vel. | Measured Vel. | Corrected Vel. |
| | d h | | | | | | | | |
| L. 979 | June 6 19·28 | 0·682 | 0·770 | 0·318 | 0·370 | 0·163 | 0·206 | 0·104 | 0·132 |
| 985 | 9 17·48 | 0·769 | 0·858 | 0·334 | 0·386 | 0·141 | 0·180 | 0·012 | 0·039 |
| 986 | 9 17·88 | 0·787 | 0·878 | 0·394 | 0·447 | 0·170 | 0·209 | 0·106 | 0·135 |
| 987 | 10 16·72 | 0·649 | 0·737 | 0·288 | 0·341 | 0·182 | 0·222 | 0·118 | 0·147 |
| 988 | 10 17·03 | 0·709 | 0·796 | 0·328 | 0·381 | 0·221 | 0·262 | 0·122 | 0·151 |
| 989 | 10 17·70 | 0·801 | 0·888 | 0·375 | 0·429 | 0·139 | 0·179 | 0·118 | 0·147 |
| 990 | 10 17·97 | 0·680 | 0·766 | 0·351 | 0·405 | 0·188 | 0·228 | 0·097 | 0·126 |
| 992 | 10 18·60 | 0·671 | 0·757 | 0·291 | 0·344 | 0·188 | 0·228 | 0·135 | 0·164 |
| 994 | 10 19·20 | 0·682 | 0·769 | 0·253 | 0·306 | 0·159 | 0·198 | 0·107 | 0·136 |
| 996 | 10 19·78 | 0·592 | 0·677 | 0·322 | 0·375 | 0·215 | 0·256 | 0·078 | 0·107 |
| 998 | 10 20·38 | 0·692 | 0·779 | 0·307 | 0·360 | 0·158 | 0·197 | 0·086 | 0·115 |
| 1000 | 10 21·00 | 0·676 | 0·752 | 0·287 | 0·340 | 0·203 | 0·244 | 0·123 | 0·152 |
| 1003 | 13 17·22 | 0·668 | 0·756 | 0·296 | 0·348 | 0·221 | 0·261 | 0·098 | 0·128 |
| 1005 | 13 18·12 | 0·651 | 0·739 | 0·266 | 0·319 | 0·176 | 0·216 | 0·135 | 0·165 |
| 1007 | 13 18·65 | 0·719 | 0·807 | 0·314 | 0·366 | 0·267 | 0·309 | 0·096 | 0·126 |
| 1011 | 15 17·35 | 0·720 | 0·810 | 0·336 | 0·389 | 0·271 | 0·313 | 0·107 | 0·138 |
| 1013 | 15 18·23 | 0·728 | 0·817 | 0·297 | 0·349 | 0·277 | 0·319 | 0·091 | 0·121 |
| 1015 | 15 18·85 | 0·729 | 0·817 | 0·295 | 0·348 | 0·216 | 0·257 | 0·097 | 0·127 |
| 1017 | 15 19·55 | 0·740 | 0·828 | 0·334 | 0·386 | 0·245 | 0·286 | 0·092 | 0·122 |
| 1018 | 15 19·78 | 0·741 | 0·829 | 0·310 | 0·363 | 0·255 | 0·296 | 0·133 | 0·164 |
| Means (Linear) | | 0·704 | 0·791 | 0·315 | 0·368 | 0·203 | 0·243 | 0·103 | 0·132 |
| Means (Angular) | | | 11°·24 | | 10°·07 | | 9°·91 | | 10°·58 |
| Prob. Error, Single Plate | | ± 0·035 | | ± 0·023 | | ± 0·030 | | ± 0·018 | |

DISCUSSION AND COMPARISON OF RESULTS

These results may now be well compared with those obtained in the λ 5600 region in the years 1911 and 1912 by J. S. Plaskett and R. E. DeLury using the same apparatus. Such a comparison is given in Table III., where the third column gives the actual measured velocities at the equator, and the fourth column gives the mean probable error for a line using all plates at all latitudes.

The most important thing to note here is that the results obtained by J. S. Plaskett in 1911 and 1912 are considerably greater than those obtained by the writer. To see if the same were the case in 1913, J. S. Plaskett measured 20 equatorial

TABLE III.

| Observer | Date | Measured Velocity | p. e. Line |
|---|---|---|---|
| J. S. Plaskett | 1911 | 2·017 | ·024 |
| J. S. Plaskett | 1912 | 2·014 | ·040 |
| R. E. DeLury | 1911 | 1·950 | ·060 |
| R. E. DeLury | 1912 | 2·006 | ·080 |
| H. H. Plaskett | 1912* | 1·993 | ·021 |
| H. H. Plaskett | 1913 | 1·991 | ·039 |

* This value obtained from the measures of five plates only.

strips, and a comparison of measures will be found in Table IV. It will be seen that the values there given are practically identical. Consequently, the value of rotation as determined by J. S. Plaskett from the 1912 plates is ·024 km. higher than the

TABLE IV.—COMPARISON OF MEASURES

| Plate | J. S. Plaskett | | H. H. Plaskett | | J−H |
|---|---|---|---|---|---|
| | Velocity 0° | Line p. e. | Velocity 0° | Line p. e. | |
| L 979 | 1·842 | ± 0·042 | 1·802 | ± 0·055 | + 40 |
| 985 | 1·781 | ·057 | 1·763 | ·029 | + 18 |
| 986 | 1·774 | ·059 | 1·774 | ·049 | 0 |
| 987 | 1·817 | ·021 | 1·794 | ·046 | + 21 |
| 988 | 1·829 | ·037 | 1·807 | ·035 | + 22 |
| 989 | 1·835 | ·044 | 1·819 | ·044 | + 16 |
| 990 | 1·851 | ·027 | 1·816 | ·023 | + 35 |
| 992 | 1·837 | ·044 | 1·845 | 067 | − 8 |
| 994 | 1·826 | ·036 | 1.872 | ·034 | − 46 |
| 996 | 1·826 | ·051 | 1·833 | ·053 | − 7 |
| 998 | 1·798 | ·056 | 1·794 | ·053 | + 4 |
| 1000 | 1·805 | ·025 | 1·803 | ·038 | + 2 |
| 1003 | 1·812 | ·035 | 1·806 | ·037 | + 6 |
| 1005 | 1·767 | ·039 | 1·776 | ·036 | − 9 |
| 1007 | 1·745 | ·036 | 1·770 | ·023 | − 25 |
| 1011 | 1·784 | ·044 | 1·820 | ·040 | − 36 |
| 1013 | 1·760 | ·037 | 1·778 | ·036 | − 28 |
| 1015 | 1·783 | ·039 | 1·818 | ·035 | − 35 |
| 1017 | 1·834 | ·038 | 1·853 | ·031 | − 19 |
| 1018 | 1·817 | ·028 | 1·790 | ·033 | + 27 |
| Means | 1·806 | ± 0·040 | 1·807 | ± 0·040 | − ·001 |
| Prob. Error, Single Plate | ± 0·021 | | ± 0·019 | | |

value of the rotation determined from the 1913 plates. This difference may be accounted for in three ways :—

(*a*) Variation in the velocity of rotation from year to year,

(*b*) Change in J. S. Plaskett's "habit" of measurement, and

(*c*) Poor quality of, or systematic errors* in, the plates.

The first two possibilities will be discussed later, but a word might be said here in regard to the character of the plates.

Since the quality of the lines in the $\lambda$ 5600 region is poor, it is evident that every precaution must be taken in exposure and development in order to ensure spectra of good quality for measurement. It is quite evident from even a cursory examination of the plates that the exposures were none too well timed. In fact, this is almost impossible, when conditions are changing from day to day, and even from hour to hour.

With regard to development, it might be advisable to try methods other than those employed. Possibly the time, or tank method might, as in other photograpdic work, give uniform and satisfactory results.

It will now be of interest to compare these results with those obtained at other institutions engaged in the same line of research. Such a comparison will be found in Table V. In the two Faye formulæ, by changing $\cos^2 \phi$ to $(1 - \sin^2 \phi)$ we obtain the formulæ in the form :—

$$(a - b \sin^2 \phi) \cos \phi = V$$
$$a' - b' \sin^2 \phi = \xi$$

where $a$ and $a'$ now give the linear and angular velocities at the equator. This puts the formulæ in a form more suited for comparison, and these are the values of $a$, $b$, $a'$, $b'$ that are given in Table V. The diversity of the results here is very remarkable

Now it is of course just possible that these discrepant results mean that the sun's velocity is variable. The writer has

* A discussion of this point will be found in either of the two papers already referred to.

TABLE V.—FORMULÆ FOR SOLAR ROTATION

| Observer | Date | V, Linear Velocities | | $\xi$, Angular Velocities | |
|---|---|---|---|---|---|
| | | a | b | a′ | b′ |
| Dunér | 1901 | 2·09 | | 14°·81 | 4°·21 |
| Halm | 1901–6 | 2·05 | | 14°·53 | 2°·50 |
| Adams | 1906–7 | 2·055 | 0·4[illegible]0 | | |
| Adams | 1908 | 2·053 | 0·546 | 14°·61 | 4°·04 |
| Adams | Mean | 2·051 | 0·501 | 14°·54 | 3°·50 |
| Storey & Wilson | 1910 | 2·08 | | 14°·75 | 3°·2 |
| J. S. Plaskett | 1911 | 2·012 | 0·523 | 14°·28 | 3°·71 |
| J. S. Plaskett | 1912 | 2·012 | 0·535 | 14°·28 | 3°·80 |
| J. S. Plaskett | Mean | 2·012 | 0·531 | 14°·28 | 3°·77 |
| DeLury | 1911 | 1·971 | 0·523 | 14°·04 | 4°·00 |
| Hubrecht | 1911 | 1·86 | | 13°·23 | 3°·2 |
| Evershed & Royds | 1912 | 1·94 | | 13°·77 | |
| Schlesinger | 1911–12 | 2·00 | | 14°·17 | 3°·4 |
| H. H. Plaskett | 1913 | 1·978 | 0·537 | 14°·04 | 3°·81 |

attempted to form a seven year period from the results given in Table V. with minima at the following years.

| | | |
|---|---|---|
| 1899·5 | 1·98 | Dunér |
| 1906·3 | 2·010 | Halm |
| 1913·5 | 1·978 | H. H. Plaskett |

While the values of velocity obtained by Halm and Dunér in the period 1899 to 1906 do not fit in very well, yet those obtained by later observers in the period 1906 to 1913 form a fairly presentable curve. There is a maximum of 2·08 km. per second from Story and Wilson's observations in 1910, while Adams' results for 1906-8 are on the ascending branch of the curve, and those of J. S. Plaskett and Schlesinger are on the descending branch. Such a period is, however, decidedly uncertain as we shall have reason to see in Section 3.

In the discussion of these results, there remains only one other point for consideration. It will be noticed that the majority of plates in 1913 were taken on four days, *i. e.*, the ninth, tenth, thirteenth and fifteenth. Using the actual measured values at the equator we have, grouping them according to days, the following :—

| | | |
|---|---|---|
| June 9 | 1·949 | 2 plates |
| 10 | 2·004 | 14 plates |
| 13 | 1·979 | 6 plates |
| 15 | 1·985 | 8 plates |

This rather remarkable result is also borne out by J. S. Plaskett's measures in the equatorial region. Some form of daily variation might be suspected if these results were sustained in the lower latitudes. This, however, is not the case, for though for any latitude each day has its own peculiar velocities, yet these velocities do not preserve the same order of magnitude.

SECTION 2. — SYSTEMATIC DIFFERENCES OF VELOCITY FOR DIFFERENT ELEMENTS.

With the exception of Adams, previous observers have been of the opinion that there is no systematic difference in velocity for different elements. J. S. Plaskett and R. E. DeLury in 1911 shewed conclusively that in the λ 5600 region there was no difference that could not be accounted for under the head of accidental error. In the as yet unpublished results of 1912 the same conclusion was reached. And in 1913 none of the lines measured showed any such effect. In Table VI. will be found a list of the algebraic residuals for each latitude and for each line. The largest algebraic residual is for the last line λ 5658·097, and as this is less than one-third the mean numerical residual, it may safely be concluded that this is accidental in character. Accordingly for the three years 1911-1913 the conclusion reached is, that there are no systematic differences of velocity for different elements in the λ 5600 region.

SECTION 3.—PERSONAL ERRORS OF MEASUREMENT

In this section nothing will be said of instrumental errors as they have been very thoroughly treated elsewhere.* Something may, however, be added to the conclusions reached by J. S.

*See the two papers by J. S. Plaskett and R. E. DeLury already referred to.

Plaskett and R. E. DeLury with regard to personal errors of measurements.

The question of measurement is very largely a psychological one. Theoretically the correct way to set on a line is on the centre of intensity. That this method of procedure is rarely if ever followed is indicated by two facts. If it were followed, all measurers would obtain the same value of the displacement for the same plate. That this is not the case is shown elsewhere.* Further, on account of the poor character of the lines used in the solar rotation, if the centre of intensity were set on,

TABLE VI.—RESIDUALS IN λ 5600

| Wave Lengths | El | Inc. | Mean Algebraic Residuals at Latitudes | | | | | | | | Mean Numl. Residual | Mean Algebc. Residual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0° | 15° | 30° | 45° | 60° | 75° | 80° | 85° | | |
| 5544·157 | Fe | 2 | - 21 | 33 | - 7 | + 10 | + 9 | + 1 | - 10 | + 9 | 48 | - 5 |
| 5560·434 | Fe | 2 | + 1 | - 15 | 5 | 5 | - 8 | + 6 | 8 | - 4 | 54 | 5 |
| 5562·933 | Fe | 2 | + 2 | - 18 | - 15 | + 5 | 0 | + 2 | + 9 | + 9 | 50 | - 1 |
| 5569·848 | Fe | 6 | - 7 | + 26 | + 18 | - 11 | - 1 | + 19 | 10 | - 26 | 43 | + 1 |
| 5576·320 | Fe | 4 | - 2 | + 19 | - 5 | + 1 | - 13 | - 25 | - 4 | + 3 | 45 | 3 |
| 5578·946 | Ni. | 1 | + 16 | 15 | + 2 | 10 | + 25 | - 9 | + 6 | + 9 | 53 | + 3 |
| 5582·198 | Ca | 4 | - 1 | + 10 | + 12 | + 11 | 32 | - 8 | + 5 | + 8 | 39 | + 1 |
| 5590·343 | Ca | 3 | + 5 | + 8 | 10 | + 5 | - 2 | - 21 | + 1 | 15 | 44 | - 4 |
| 5601·505 | Ca | 3 | + 1 | 0 | + 1 | - 24 | - 11 | + 6 | - 9 | - 15 | 44 | - 6 |
| 5624·769 | FeV | 3 | - 1 | + 7 | + 15 | 0 | + 19 | + 3 | + 5 | + 12 | 44 | + 8 |
| 5638·488 | Fe | 3 | - 6 | + 18 | - 8 | - 7 | 0 | + 5 | + 8 | - 11 | 41 | 0 |
| 5658·097 | V | 2 | + 13 | - 7 | + 7 | + 11 | + 11 | + 25 | + 22 | + 27 | 46 | + 14 |
| Prob. Error, Single Line | | | 38 | 37 | 41 | 41 | 41 | 38 | 43 | 36 | | |

the magnitudes of the probable errors might be reasonably expected to be greater than they are. There are possibly two reasons why a different mode of setting is used, namely: mental fatigue and desire. Owing to the varying character of the lines, each setting on the centre of intensity would involve a fresh expenditure of mental energy, which would tend to become very tiring. Accordingly a mode of setting might be adopted which would involve the least expenditure of mental energy, and would allow the measurement to be performed in a purely mechanical

* See the two papers by J. S. Plaskett and R. E. DeLury already referred to.

fashion. Mental desire may also, and probably does, enter into the question. The part of the line set on may be dictated by some prepossession of the mind seeking a certain result. It is very probably some combination of these "complexes" that gives an individuality, and a character, to each person's measures. As such a character is due to the action of the mind, the psychological law of association enters, and this character becomes a more or less permanent feature of the measures. It can be well understood that such an association would become much weakened with the passage of time, and thus, if measurement were altogether discontinued for a sufficiently long interval, the character of one's measures would be lost. In commencing to measure again it seems highly probable that the character of the measures would be changed.

To determine the influence exerted by this character, or, in other words, to determine the personal equation of each measurer, is a question of no little importance. It seems to the writer that a determination could be made by some such method as the following. If six plates, say, of good quality were sent to each observer in turn with instructions to measure and compare with plates of his own, much valuable information could be obtained. From all the measures on the six plates a mean value could be obtained for each from which a correction might be determined for each observer.

Until something of this nature is done it is hopeless to expect definite knowledge with regard to the solar rotation. It is evident that a variation in velocity, such as was mentioned in Section 1, would entirely collapse if certain not unlikely corrections were applied to each observation. The need for such an investigation is thus plainly seen.

With regard to J. S. Plaskett's velocity obtained from the 1913 plates, as compared with that from the 1911 and 1912 plates, much might be said. The three possibilities mentioned in Section 1 as explaining this difference, all seem plausible in the light of further evidence presented in that section and this. If the fall in value be due to a variation in the sun's velocity, that excludes to a large extent the possibility of a change in J. S. Plaskett's habit of measurement. So, also, if we admit a change in his habit of measurement, then that excludes very largely the possibility of a variation in velocity. The third possibility, that of an instrumental error, seems from every view point the most likely. The large differences due to instrumental error are discussed elsewhere.* They would more than cover the difference or fall in value between 1912 and 1913. The problem will be finally settled only when J. S. Plaskett has measured the plates in the $\lambda$ 4250 region for 1913, and has also remeasured some of his earlier plates.

## Summary

The conclusions from this investigation may be briefly enumerated as follows:—

(*a*) The 1913 values of the solar rotation may be represented by the formulæ:

$$(1{\cdot}441 + 0{\cdot}537 \cos^2 \phi) \cos \phi = V,$$
$$10^\circ{\cdot}23 + 3^\circ{\cdot}81 \cos^2 \phi = \xi.$$

(*b*) There is no evidence of systematic differences of velocity for different elements.

(*c*) It is at present impossible to settle the question of a variation in the solar rotation, or any similar problem, until the personal errors of measurement of each observer has been determined.

In conclusion it gives me great pleasure to acknowledge the obligation I am under to Dr. King for permission to publish these results.

* See the two papers by J. S. Plaskett and R. E. DeLury already referred to.

Dominion Observatory,
Ottawa, Canada,
August 24th, 1914.

# ERRORS IN LONGITUDE, AZIMUTH AND LATITUDE DETERMINATIONS—II.

By F. A. McDiarmid

## AZIMUTH

The azimuth of a point on the earth's surface is the angle contained between the plane of the meridian and the vertical plane which passes through this point and the eye of the observer.

Since the vertical plane is determined by the direction of the plumb line, and this line may deviate from the true norma to the earth's surface, a corresponding change in azimuth must exist. There is therefore *astronomical* and *geodetic* azimuth.

The *astronomical azimuth* of a point is the angle between two planes drawn through the plumb line at the point of observation, the first plane parallel to the earth's axis, and the second passing through the point.

The *geodetic azimuth* is the angle between two planes drawn through the normal to the earth's surface at the point of observation, the first plane passing through the earth's axis and the second through the point.

In this paper astronomical azimuth alone will be considered. Extreme accuracy in azimuth observations is necessary in connection with the geodetic operations of a primary triangulation and with the establishment of international or provincial boundaries. The principal methods employed in such work by the Canadian astronomers will be given, together with some of the results obtained therefrom.

## THE INSTRUMENTS

The instruments employed (by the Dominion Observatory) in field azimuth determination are: a twelve-inch alt-azimuth having a horizontal circle finely graduated and read with micrometer microscopes, and the astronomical transit used in time work. With the latter instrument the mark is placed nearly in the meridian of the observer, and the azimuth of the line connecting the observatory and the mark determined. That line can then be connected to any series of triangulation required. With the twelve-inch alt-azimuth the mark can be placed in any direction whatever from the observatory, and the angle between the mark and star can be read on the horizontal circle. With the transit instrument used for azimuth determinations the polar stars must be observed as they cross the meridian, while with the other instrument the stars can be observed at any hour angle whatever.

The stars generally used in azimuth determinations are α Ursæ Minoris, λ Ursæ Minoris, δ Ursæ Minoris, 51 Hev. Cephei, and Bradley 1672; but the writer has used stars of as low a declination as 82°, with a fair measure of success. All the observations on the stars of smaller declination were made with the transit in the meridian. When stars of declinations ranging from 82° to 89° are used, there is placed at the disposal of the observer a list of about fifteen or twenty stars crossing the meridian at times suitable for observing.

THE SIGNAL.

Precise azimuth observations are carried on at night, and an illuminated mark is required. A convenient mark is a wooden box firmly mounted over the point whose direction from the observatory is required, the light from a lantern or carbide lamp being thrown through a hole in the front. This mark must be placed far enough from the observatory so that no change in the focus of the telescope will be necessary between the observations on star and mark. About a mile will generally be sufficient. Fairly good observations have been obtained at a less distance, but it should always be attempted to get the mark at least one mile from the observatory. It is also well to have the azimuth line pass a considerable distance above the surface of the ground, and so it is well to place the signal on a high elevation; the higher the line of sight above the ground, the steadier the light may be expected to show, and the smaller the errors from lateral refraction.

The diameter of the aperture through which the light is thrown should be adjusted with reference to its distance from the observatory, the power of the telescope, and the local atmospheric conditions. The aperture should be such as to subtend at the observer an angle between 1″ and 0″·5.

The distance to the mark being known, it is easy to compute the size of the hole required.

| Distance of mark | | Diameter of aperture | |
|---|---|---|---|
| Km | St. miles | Max. | Min. |
| | | mm | mm |
| 1·5 | ·9 | 7 | 4 |
| 2·0 | 1·2 | 10 | 5 |
| 2·5 | 1·6 | 12 | 6 |
| 3·0 | 1·9 | 15 | 8 |
| 4·0 | 2·5 | 19 | 10 |
| 6·0 | 3·7 | 29 | 14 |
| 10·0 | 6·2 | 48 | 24 |

In the report of the United States Coast and Geodetic Survey for 1897-98 the above table is given. In our work here in Canada we found a much smaller aperture preferable. In some observations at Atlin, B. C., in 1911, an aperture of diameter one-eighth of an inch at a distance of one and a quarter miles was found very satisfactory. The light was from an ordinary coal oil lantern and it showed about the brightness of a fourth magnitude star. If a carbide lamp had been the source of illumination, the aperture could doubtless have been made smaller and the result would likely have been even more satisfactory.

METHOD OF OBSERVATION

With both the alt-azimuth instrument and the transit telescope the method of observation is essentially the same. A complete observation consists of ten readings on the mark; ten on the star, noting the time; reading the striding level; reversing the telescope and again reading the striding level; ten readings on the star; and ten readings on the mark. With the alt-azimuth instrument it is necessary to read the horizontal circle, both on star and mark. Both instruments are fitted with an eye-piece micrometer; the one used on the transit instrument is that employed in time work, and the observations on the star are recorded on the chronograph. As the star readings in the two positions of the telescope are taken over the same part of the field, the mean of the chronograph readings will be the star's time of transit across the line of collimation. If we assume $a$ to be the mean of the readings on the mark with the telescope in one clamp, and $b$ the mean of the mark readings in the opposite clamp, then $(a + b)/2$ is the reading of the line of collimation, and the mark is $(a - b)/2$ from the line of collimation.

As in time determinations, so in azimuth observations one very fruitful source of error is from poor level determination. The value of the level correction is determined directly from readings of the striding level, and extreme care must be taken to remove all possible level errors as they enter directly into the azimuth results with sometimes more than their full values. If $b$ is the inclination of the axis when west end of axis is high and if $z$ is the zenith distance of the star, then the correction to the azimuth due to level is $b \cot z$. In high latitudes the value of $z$ is generally small, and hence the correction for level is considerable.

An observation for azimuth may be taken on a polar star at any hour angle, and the reduction made by the following formula: —

$$-\tan A = \frac{\sin t}{+\cos\phi\tan\delta - \sin\phi\cos t};$$

where $A$ is the azimuth to be determined,
$\phi$ is the latitude of the place of observation,
$\delta$ is the declination of the star,
and $t$ is the hour angle of the star.

If $\alpha$ is the right ascension of the star,
and $T$ is the chronometer time of observation,
at $\Delta T$ is the error of the chronometer,
then $t = ( T + \Delta T - \alpha )$.

$\Delta T$ may be determined in several ways, the best of which is by observing time stars in the meridian, or time stars in the vertical of Polaris. If the azimuth observations are made in the meridian and the transit instrument is being used, then with comparatively little labor the clock error can be determined by transits of a few stars. When the alt-azimuth instrument is the instrument employed then the best determination of time is obtained from observations in the vertical of Polaris.

Let $\alpha$ and $\alpha'$ be the right ascensions of Polaris and the time star respectively, and $T$ and $T'$ be their times of transit across a certain vertical plane; $\delta$, the declination of the south star; $P$, the polar distance of Polaris in seconds of arc; $\phi$, the latitude of the observatory; and $t$, the hour angle of the time star.

Also let $\Delta = ( \alpha - \alpha' ) + ( T - T' )$;

Then $t = 15 \ ( P \sin \Delta ) \ ( 1 \times P \cos \Delta \tan \delta \sin 1'' ) \ (\tan \phi - \tan \delta )$.

The star's time of transit (over vertical of Polaris) $= \alpha + t$;
and the chronometer error $= \alpha + t - T'$.

By observing one star with circle right and a second with circle left, and taking the mean of the two results we get a clock correction free from collimation error. A time determination obtained in this way is easily correct within the limits required in azimuth work.

On the following pages are given the computations of some observations taken at Edmundston, N.B., by this method.

## TIME OBSERVATIONS

STATION, Edmundston DATE, October 31, 1909

| CIRCLE WEST | | CIRCLE EAST | |
|---|---|---|---|
| Polaris *a′* 1 27 31·50 | *T″* = 20 55 33·0 | Polaris *a′* = 1 27 31·5 | *T″* = 21 07 06 |
| B. J. 792 *a* 21 01 38·29 | *T′* = 21 02 38·0 | B. J. 797 *a* = 21 09 05·08 | *T′* = 21 11 39·5 |
| Difference 4 25 53·21 | 7 05·0 | Difference = 4 18 26·42 | 4 33·5 |
| ″ 7 05·0 | | ″ 4 33·5 | |
| Δ 4 32 58·21 | | Δ = 4 22 59·92 | |
| | 1s = 4228·41 | | 1s = 4228·41 |
| φ 47° 22′ | Nat tan = 1·0862 | φ = 47 22 | Nat tan = 1·0862 |
| δ 43° 34′ | Nat tan = ·9512 | δ = 29 51 | Nat tan = ·5739 |
| φ − δ | tan φ tan δ = ·1350 | φ δ = | tan φ − tan δ = ·5123 |
| log *P* = 3·6261771 | | 3·6261771 | |
| sin Δ = 99679040 | | 9·9598806 | |
| *P* sin Δ = 3·5940811 | = 3927·18 | 3·5860577 | = 3855·30 |
| log *P* = 3·6261771 | | 3·6261771 | |
| cos Δ = 9·5689980 | | 9·6135493 | |
| tan δ = 9·9782620 | | 9·7588096 | |
| sin 1″ = 4·6355749 | | 4·6855749 | |
| 1·4530931 | = 28·39 | 1·2701686 | = 18·62 |
| | *p* = 3955·57 | | 3873·92 |
| log *p* = 3·5972091 | | 3·5881506 | |
| log (tan φ − tan δ = 9·130338 | | 9·7095244 | |
| log *t* (in arc) = 2·7275429 | | 3·2976750 | |
| log 15′ = 1·1760913 | | 1·1760913 | |
| log *t* (in time) = 1·5514516 | | 2·1215831 | |
| *t* = 35·60 | | 132·32 | |
| *a* = 21 01 38·29 | | 21 09 05·08 | |
| *t* = 35·60 | | 2 12·32 | |
| S. T. of transit = 21 02 13·89 | | 21 11 17·40 | |
| *T′* = 21 02 38·60 | | 21 11 59·5 | |
| Chronometer error = − ·24s·1 | | − 22·1 | |

At Mean *T*. 21h 07m Δ *T* = − 23s·1

## TIME OBSERVATIONS

STATION, Edmundston DATE, October 31, 1909

| CIRCLE WEST | | | CIRCLE EAST | | |
|---|---|---|---|---|---|
| Polaris $a'$ | 1 27 31·50 | $T''$ = 2 15 20·50 | Polaris $a'$ = | 1 27 31·5 | $T'$ = 2 24 28 |
| B. J. 85 $a$ | 3 23 21·95 | $T$ = 2 22·49 | B. J. 89 $a$ = | 2 33 41·72 | $T$ = 2 33 15·5 |
| Difference | 2 30 49·55 | 7 28·50 | Difference = | 22 53 49 78 | 8 47 5 |
| ″ | 7 28 58 | | ″ | 8 47·5 | |
| $\Delta$ | 23 11 38·05 | | $\Delta$ = | 23 02 37·28 | |
| | | C = 4228·41 | | | |
| $\phi$ | 47 22 | Nat tan = 1·0862 | $\phi$ = | 47·22 | Nat tan = 1·0862 |
| $\delta$ | 8 03 | Nat tan = 1414 | $\delta$ = | 21·34 | Nat tan = ·3953 |
| $\phi - \delta$ | | tan $\phi$ − tan $\delta$ = 9448 | $\phi - \delta$ = | | tan $\phi$ − tan $\delta$ = ·6909 |
| log $P$ = | 3·6261771 | | | 3·6261771 | |
| sin $\Delta$ = | 9·3201345$_n$ | | | 9·3940230$_n$ | |
| $P$ sin $\Delta$ = | 2·9463116 | = − 883·72 | | 3·0202001 | = − 1047·60 |
| log $P$ = | 3·6261771 | | | 3·6261771 | |
| cos $\Delta$ = | 9·9902561 | | | 9·9862443 | |
| tan $\delta$ = | 9·1505441 | | | 9·5968776 | |
| sin 1″ = | 4·6855749 | | | 4·6855749 | |
| | ·3988638 | = − 2·51 | | ·9150740$_n$ | = − 8·22 |
| | | $p$ = − 886·23 | | | − 1055·82 |
| log $p$ = | 2·9475464 | | | 3·0235899$_n$ | |
| log (tan $\phi$ − tan $\delta$) = | 9·9753399 | | | 9·8394152 | |
| log $t$ (in arc) = | 2·9228863$_n$ | | | 2·8630051 | |
| log 15′ = | 1·1760913 | | | 1·1760913 | |
| log $t$ (in time) = | 1·7467950$_n$ | | | 1·6869138 | |
| $t$ = | − 55·82 | | | − 48″·63 | |
| $a$ = | 2 23 21·95 | | | 2 33 41·72 | |
| $t$ = | 55·82 | | | 48·63 | |
| S. T. of transit = | 22 22 6·13 | | | 2 32 53·09 | |
| $T$ = | 2 22 49 | | | 2 33 15·5 | |
| Chronometer error = | − 22″·9 | | | − 22″·4 | |

At Mean 2h 28m − 22″·6

## REDUCTION OF AZIMUTH OBSERVATIONS

If $A$ is the azimuth required ; $t$, the hour angle of the star at the instant of observation ; $\phi$, the latitude of the place of observation ; $\delta$, the declination of the star ; then the azimuth is given by the formula :—

$$\tan(-A) = \frac{\sin t}{\cos\phi \tan\delta - \sin\phi \cos t},$$

$$= \frac{\sec\phi \cot\delta \sin t}{1 - \cot\delta \tan\phi \cos t}.$$

$$= \frac{\sec \phi \cot \delta \sin t}{1 - a};$$

where $a = \cot \delta \tan \phi \cos t$.

Now log $(1 - a)$ is tabulated for values of log $a$ when log $a$ is not greater than 9·00 and not less than 9·00$n$. For stars of declination greater than 88°, log $a$ is always between these limits.

The curvature correction is always small, but not negligible. It is given by the formula:—

$$\text{Curvature correction} = \tan A \frac{1}{n} \Sigma \frac{2 \sin^2 \frac{1}{2} T}{\sin 1''}$$

where $T_1$, $T_2$, $T_3$, .... $T_n$ are differences between the times of the separate observations and the mean. If the star crosses the meridian during the progress of the observations, the curvature correction will be zero. This is the case with observations taken with the transit instrument in the meridian.

Because of the rapid motion of the observer, due to the rotation of the earth on its axis the star is seen slightly displaced from its real position. The correction for diurnal aberration is given by

$$0''\!\cdot\!32 \frac{\cos A \cos \phi}{\sin z},$$

where $A$ is the azimuth of the star, $\phi$ is the latitude of the place of observation, and $z$ is the zenith distance of the star.

On the following pages will be found azimuth observations taken at Edmundston, N.B., with the alt-azimuth instrument.

## AZIMUTH COMPUTATION

STAR α Ursæ Minoris — INSTRUMENT 12″ Azimuth

DATE October 31, 1909 — STATION Edmundston

OBSERVER, F. A. McDiarmid

| Explanation | Set 1 Sheet | Set 2 Sheet | Set 3 Sheet | Set 4 Sheet | Set 5 Sheet |
|---|---|---|---|---|---|
| $t$ in time | − (5h 49m 49s·3) | − (3h 52m 27s·6) | − (3h 02m 27s·6) | − (2h 22m 23s·1) | − (1h 36m 21s·0) |
| $t$ in arc | − 87° 27′ 19″·5 | − (58° 06′ 54″·0 | − (45 36 54·0) | − (35° 35′ 46·5) | − (24 05 15·0) |
| $\delta$ | 88° 49′ 31″·50 | 88 49 31·53 | 88° 49′ 31″·53 | 88 49 31·55 | 88 49 31·57 |
| cot $\delta$ | 8·3117307 | 8·3117271 | 8·3117270 | 8·3117261 | 8·3117241 |
| tan $\phi$ | ·0359470 | ·0359470 | ·0359470 | ·0359470 | ·0359470 |
| cos $t$ | 8·6473513 | 9·7228116 | 9·8447730 | 9·9101648 | 9·9604343 |
| log $a$ | 6·9950290 | 8·0704857 | 8·1924470 | 8·2578379 | 8·3081054 |
| cot $\delta$ | 8·3117307 | 8·3117271 | 8·3117270 | 8·3117261 | 8·3117241 |
| sec $\phi$ | ·1692315 | ·1692315 | ·1692315 | ·1692315 | ·1692315 |
| sin $t$ | 9·9995715n | 9·9289640n | 9·8540999n | 9·7649750n | 9·6107999 |
| log $\frac{1}{1-a}$ | ·0004306 | ·0051388 | ·0068177 | ·0079358 | ·0089192 |
| log (− tan $A$) | 8·4809643n | 8·4150604n | 8·3418731n | 8·2538684 | 8·1006747n |
| $A$ | + 1° 44′ 01″·40 | + (1 29 22·79) | + (1 15 31·33) | + (1 01 40·39) | + 0 43 20·62 |
| $\tau$ and $\frac{2 \sin^2 \frac{1}{2} \tau}{\sin 1''}$ | 15m 05s 446·55 | 13 35·7 362·80 | 10 59 7 237·32 | 11 18·2 250·82 | 13 23·3 351·84 |
| | 9 09 164·37 | 8 31·7 142·78 | 6 50 7 92·00 | 7 07·2 99·52 | 8 56·3 156·84 |
| | 5 53 67·96 | 4 37·7 42·06 | 2 47·7 15·34 | 4 03·2 32·25 | 5 35·3 61·31 |
| | 5 22 56·55 | 5 32·3 60·22 | 2 30·3 12·32 | 3 23·8 22·65 | 2 29·7 12·20 |
| | 9 57 194·36 | 8 50·3 153·36 | 6 41·3 87·83 | 7 42·8 116·80 | 11 16·7 249·71 |
| | 14 48 429·93 | 12 22·3 300·45 | 10 26·3 213·90 | 11 21·8 253·48 | 14 08·7 392·73 |
| Mean | 226·62 | 176·95 | 109·62 | 129·25 | 204·11 |
| Log of mean | 2·3552982 | 2·2478506 | 2·0398898 | 2·1114306 | 2·3098643 |
| Log of curvature | ·8362625 | ·6629090 | ·3817629 | ·3652990 | ·4105390 |
| Curvature cor. | − 6″·86 | − 4·60 | − 2″·42 | − 2·32 | − 2·59 |
| Az. of star | + 1° 43′ 54″·54 | + (1 29 18·19) | + 1 15 28·91 | + 1 01 38 07 | + 0 43 18·03 |
| Reading on star | 180 40 15·45 | 0 31 26·16 | 0 17 31·25 | 180 03 43·66 | 359 45 26·10 |
| Reading on north | 179° 02′ 21″·91 | 359 02 07 97 | 359 02 10·34 | 179 02 05·59 | 359 02 08·07 |
| Reading on line | 2 41 24·80 | 182 41 11·58 | 182 41 13·82 | 2 41 11·34 | 182 41 13·63 |
| Az. of line | 183 39 03·89 | 183 39 3·61 | 183 39 03·48 | 183 39 05·75 | 183 39 05·56 |

AZIMUTH COMPUTATION—(*Continued*)

STAR α Ursæ Minoris — INSTRUMENT 12" Azimuth

DATE October 31, 1909 — STATION Edmundston

OBSERVER, F. A. McDiarmid

| Explanation | Set 6 Sheet | Set 7 Sheet | Set 8 Sheet | Set 9 Sheet | Set 10 Sheet |
|---|---|---|---|---|---|
| $t$ in time | − (0h 55m 16s·5) | − (0h 15m 20s·1) | 0h 25m 26s·7 | 1h 20m 26s·5 | 1h 55m 14s·5 |
| $t$ in arc | − 13 47 07·5 | − (3° 50′ 1″·5) | 6 21 40·5 | 20 06 37·5 | 28 48 37·5 |
| $\delta$ | 88 49 31·58 | 88 49 31·59 | 88 49 21·60 | 88 49 31·62 | 88 49 31·63 |
| cot $\delta$ | 8·3117221 | 8·3117211 | 8·3117201 | 8·3117181 | 8·3117171 |
| tan $\phi$ | ·0359470 | ·0359470 | ·0359470 | ·0359470 | ·0359470 |
| cos $t$ | 9·9872443 | 9·9990270 | 9·9973178 | 9·9726803 | 9·9426127 |
| log $a$ | 8·3349134 | 8·3466951 | 8·3449849 | 8·3203454 | 8·2902768 |
| cot $\delta$ | 8·3117221 | 8·3117211 | 8·3117201 | 8·3117181 | 8·3117171 |
| sec $\phi$ | ·2692315 | 1692315 | ·1692315 | 1692315 | 1692315 |
| sin $t$ | 9·3781275$n$ | 8·8251770 | 9·0445273 | 9·5303443 | 9·6829686 |
| log $\frac{1}{1-a}$ | ·0034951 | ·0037570 | ·0097187 | ·0091772 | ·0085575 |
| log (− tan $A$) | 7·8685762$n$ | 7·3158866$n$ | 7·5351976 | 8·0264711 | 8·1724747 |
| $A$ | + (0 25 24·03 | + 0 07 05·98 | − 0 11 47·33 | − 0 36 32·20 | − 0 51 08·09 |
| $\tau$ and $\frac{2 \sin^2 \frac{1}{2} \tau}{\sin 1''}$ | 15 41·8 483·59 | 11 16·2 249·34 | 10 03 198·25 | 9 30·8 177·68 | 9 36·8 181·43 |
| | 9 19·8 170·90 | 7 51·2 121·08 | 7 30 110·44 | 6 13·8 76·25 | 6 05·8 72·98 |
| | 4 36·8 41·78 | 2 28·2 11·97 | 4 09 33·81 | 3 02·8 18·23 | 3 47·8 28·30 |
| | 6 41·2 87·79 | 3 04·8 18·57 | 2 48 15·39 | 2 38·2 13·64 | 2 47·2 15·23 |
| | 9 48·2 188·68 | 8 03·8 127·64 | 8 18 135·25 | 6 05·2 72·34 | 6 03·2 71·94 |
| | 13 09·2 339·61 | 10 26·8 214·24 | 10 36 220·58 | 10 04·2 199·07 | 10 40·2 223·50 |
| Mean | 218 72 | 123·81 | 118·96 | 92·86 | 98·90 |
| Log of mean | 2·3398885 | 2·0927557 | 2·0754010 | 1·9678287 | 1·99951963 |
| Log of curvature | ·2084647 | 9·4086423 | 9·6105986 | 9·9942998 | ·1676710 |
| Curvature cor. | − 1·62 | − ″·26 | + ″·41 | + ″·99 | 1″·49 |
| Az. of star | + 0° 25′ 22″·41 | 0 07 06·72 | − 0 11 40·92 | − 0 36 31·21 | − 0 51 06·60 |
| Reading on stars | 179 27 30 01 | 359 09 15·23 | 178 50 19·60 | 358 25 34·91 | 178 10 58·64 |
| Reading on north | 179 02 07·60 | 359 02 8·51 | 179 02 05·52 | 359 02 06·12 | 179 02 05·24 |
| Reading on line | 2 41 10·96 | 182 41 12·05 | 2 41 11·05 | 182 41 09·31 | 2 41 12 05 |
| Az. of line | 183° 39′ 03″·36 | 183 39 03·54 | 183 39 04.53 | 183 39 03·19 | 183 39 06·81 |

Computer F. A. McDIARMID

Edmundston, N.B., 31 October 1909.

Azimuth of line joining Astronomical Observatory at Edmundston to monument 575 of the International Boundary Survey.

| Number of Set | Azimuth of Line | | | v | v² |
|---|---|---|---|---|---|
| | ° | ′ | ″ | ″ | |
| 1 | 183 | 39 | 03·89 | 0·48 | ·2304 |
| 2 | " | " | 03·01 | ·76 | ·5776 |
| 3 | " | " | 03·48 | ·89 | ·7921 |
| 4 | " | " | 05·75 | - 1·38 | 1·9044 |
| 5 | " | " | 05·56 | - 1·19 | 1·4161 |
| 6 | " | " | 03·36 | 1·01 | 1·0201 |
| 7 | " | " | 03·54 | ·83 | ·6889 |
| 8 | " | " | 04·53 | - ·16 | ·0256 |
| 9 | " | " | 03·19 | 1·18 | 1·3924 |
| 10 | " | " | 06·81 | - 2·44 | 5·9536 |
| | | | | | 14·0012 |

$$\text{Probable error} \pm \cdot 6745 \sqrt{\frac{14 \cdot 0012}{10 \times 9}} = \pm \cdot 26$$

Mean azimuth 183° 39′ 04″·37 ± ·26.

Diurnal aberration ·32

Azimuth of line 183° 39′ 04″·69 ± ·26.

Observations for azimuth were made in 1907 on the 141st meridian for the purpose of determining the boundary line between the district of Alaska and the Yukon territory. The observations were made with an astronomical transit by the 'eye and ear' method of observation. Mr. G. Clyde Baldwin represented the United States government, and the writer the Canadian government. The following are the results :—

Final Azimuth Results 141st Meridian at Yukon River Crossing, boundary between Alaska and Canada.

F. A. McDiarmid, Observer.

| Date | Star | Azimuth | v | v² |
|---|---|---|---|---|
| 1907 | | ° ′ ″ | | |
| April 29 | α Ursæ Minoris | 180 00 01·94 | − ·19 | ·0361 |
| " 30 | α " " | 179 59 59·83 | 1·92 | 3·6864 |
| May 1 | α " " | 180 00 01.76 | − ·01 | ·0001 |
| " 2 | α " " | 180 00 01·97 | − ·13 | ·0169 |
| April 30 | 6 Ursæ Minoris | 180 00 01·94 | − ·19 | ·0361 |
| May 2 | 6 " " | 180 00 01·91 | − ·16 | ·0256 |
| April 30 | 43 Helvetii Cephei | 180 00 01·64 | ·11 | ·0121 |
| May 2 | 43 Helvetii Cephei | 180 00 01·34 | ·41 | ·1681 |
| April 30 | Groombridge 944 | 180 00 01·63 | ·12 | ·0144 |
| " 30 | δ Ursæ Minoris | 180 00 02·33 | − ·58 | ·3364 |
| May 2 | δ " " | 180 00 03·10 | − 1·35 | 1·8225 |
| " 2 | Groombridge 750 | 180 00 01·66 | ·09 | ·0081 |
| | | | | 6·1628 |

Mean 180° 00′ 01″·76.

Probable error $= \pm \cdot 6745 \sqrt{\dfrac{6 \cdot 1628}{12 \times 11}} = \pm \cdot 145.$

Azimuth of mark = 180° 00′ 01″·76 ± ·145.

Final Azimuth Results, 141st Meridian at Yukon River Crossing, boundary between Alaska and Canada.

G. Clyde Baldwin, Observer.

| Date | Star | Azimuth | v | v² |
|---|---|---|---|---|
| 1907 | | ° ′ ″ | | |
| May 1 | α Ursæ Minoris | 180 00 03·10 | − ·36 | ·1296 |
| " 1 | 43 Helvetii Cephei | " " 02·29 | + ·45 | ·2025 |
| " 1 | Groombridge 750 | " " 03·77 | − 1·03 | 1·0609 |
| " 1 | " 944 | " " 03·30 | − ·56 | ·3136 |
| " 1 | δ Ursæ Minoris | " " 02·54 | + ·20 | ·0400 |
| " 7 | α " " | " " 04·17 | − 1·43 | 2·0449 |
| " 8 | α " " | " " 04·19 | − 1·45 | 2·1025 |
| " 8 | 43 Helvetii Cephei | " " 04·50 | − 1·76 | 3·0076 |
| " 14 | α Ursæ Minoris | " " 01·33 | + 1·41 | 1·9881 |
| " 14 | 43 Helvetii Cephei | " " 01·28 | + 1·46 | 2·1316 |
| " 14 | Groombridge 750 | " " 02·15 | + ·59 | ·3481 |
| " 14 | δ Ursæ Minoris | " " 00·20 | + 2·54 | 6·4516 |
| | | | | 19·9110 |

Mean = 180° 00′ 02″·74.

Probable error $= \pm \cdot 6745 \sqrt{\dfrac{19 \cdot 9110}{12 \times 11}} = \pm {}'' \cdot 262.$

Azimuth of mark = 180° 00′ 02″·74 ± ″·262.

Other azimuth observations with the transit instrument were made at North Portal, Sask. ; Coutts, Alta. ; Emerson, Man. ; Hazelton, B.C. ; and Atlin, B.C. As time observations for longitude were made at all these stations on the same nights as the azimuth observations, a splendid opportunity was afforded of comparing the azimuth as determined from a time set with the azimuth from a direct observation.

North Portal. F. A. McDiarmid, Observer.

| Date | Star | Reading on Mark | Azimuth of Collimation | Azimu h of Line |
|---|---|---|---|---|
| 1910 | | " | " | " |
| July 11 | α Ursæ Minoris | – 02·98 | – 04·96 | – 07·94 |
| " 12 | α " " | – 02·95 | – 05·59 | – 08·54 |
| " 12 | 51 Hev. Cephei | 2·95 | – 09·73 | – 12·68 |
| " 12 | 76 D aconis | – 02·95 | – 06·94 | – 09·89 |
| " 12 | I. H. Draconia | – 02·95 | – 08·43 | – 11·38 |
| " 12 | 30 Hev. Cephei | – 02·95 | – 07·90 | – 10·85 |
| " 12 | δ Ursæ Minoris | – 02·95 | – 08·20 | – 11·15 |
| " 13 | α " " | – 02·76 | – 05·52 | – 08·28 |
| " 13 | 30 Hev. Cephei | – 02·76 | – 06·74 | – 09·50 |
| " 13 | ε Ursæ Minoris | – 02·76 | – 07·90 | – 10·66 |
| " 13 | δ " " | – 02·76 | – 07·66 | 10·36 |
| " 14 | ε " " | – 02·71 | – 06·66 | – 09·37 |
| " 16 | ε " " | – 03·84 | – 04·89 | – 08·73 |
| " 18 | ε " " | 03·73 | – 04·65 | – 08·38 |
| " 19 | ε " " | – 24·51 | + 16·45 | – 08·06 |
| " 20 | ε " " | – 24·51 | + 16·16 | – 08·35 |

Mean – 09″·63.

Azimuth of mark 359° 59′ 50″·37 ± ·24

Azimuth of mark from time sets 359° 59′ 50″·89.

COUTTS, ALTA. F. A. MCDIARMID, Observer.

| Date | Star | Azimuth of Collimation | Reading on Mark | Azimuth of Mark |
|---|---|---|---|---|
| | | " | " | " |
| 1910 | | | | |
| Aug. 25 | α Ursæ Min. | − 05·01 | − 23·12 | − 28·13 |
| " 25 | δ " " | − 05·71 | − 23·12 | − 28·83 |
| " 25 | 51 H. Cephei | 05·33 | − 23·12 | − 28·45 |
| " 25 | 76 Draconis | − 01·78 | − 23·12 | − 24·90 |
| " 25 | I. H. Draconis | − 03·77 | − 23·12 | − 26·89 |
| " 25 | 30 H. Camel. | − 02·83 | − 23·12 | 25·95 |
| " 25 | 39 H. Cephei | − 05·90 | − 23·12 | − 29·02 |
| " 29 | 76 Draconis | − 01·26 | − 23·19 | − 24·45 |
| " 29 | I. H. Draconis | − 05·26 | − 23·19 | − 28·45 |
| Sept. 2 | α Ursæ Min. | − 10·58 | − 13·89 | 24·47 |
| " 2 | δ " " | − 13·85 | − 13·89 | − 27·74 |
| " 2 | 76 Draconis | − 12·29 | − 13·89 | − 26·18 |
| " 2 | I. H. Draconis | − 16·16 | − 13·89 | − 30·05 |
| " 2 | 30 H. Camel. | − 12·86 | − 13·89 | − 26·75 |
| " 2 | 39 H. Cephei | 14·90 | − 13·89 | − 28·79 |
| " 2 | Bradley 1672 | − 14·94 | − 13·89 | − 28·83 |
| " 2 | 43 Hel. Cephei | − 14·06 | − 13·89 | − 27·95 |
| " 4 | 76 Draconis | − 12·46 | − 14·85 | − 27·31 |
| " 4 | I. H. Draconis | − 14·27 | − 14·85 | − 29·12 |
| " 7 | 30 H. Camel. | − 10·06 | − 17·38 | − 27·44 |
| " 9 | α Ursæ Min. | − 12·56 | − 14·36 | − 26·92 |
| " 9 | 76 Draconis | − 12·65 | − 14·36 | − 27·01 |
| " 9 | I. H. Draconis | − 12·02 | − 14·36 | − 26·38 |
| " 9 | 30 H. Camel. | 11·55 | − 14·36 | − 25·91 |
| " 11 | 76 Draconis | − 10·56 | 16·90 | − 27·46 |
| " 11 | I. H. Draconis | − 11·90 | − 16·90 | − 28·80 |

Mean − 27″·39.

Azimuth of mark from direct observations 359° 59′ 32″·61
± ″·20

Azimuth of mark from time sets 359° 59′ 32″·30

EMERSON, MAN. F. A. McDIARMID, Observer.

| Date | Star | Azimuth of Collimation | Reading on Mark | Azimuth of Mark |
|---|---|---|---|---|
| 1910 | | ″ | ″ | ″ |
| Sept. 17 | 30 H. Cephei | − 14·74 | − 29·09 | − 43·83 |
| " 17 | 39 H. Camel. | − 18·02 | − 29·09 | − 47·11 |
| " 17 | 76 Draconis | − 14·52 | − 29·09 | − 43·61 |
| " 17 | I. H. Draconis | − 14·86 | − 29·09 | − 43·95 |
| " 18 | δ Ursæ Min. | − 10·52 | − 29·52 | − 40·04 |
| " 19 | 30 H. Cephei | − 14·02 | − 26·73 | − 40·75 |
| " 19 | 39 H. Camel. | − 17·43 | − 26·73 | − 44·16 |
| " 19 | δ Ursæ Min. | − 12·90 | − 26·73 | − 39·63 |
| " 19 | 76 Draconis | − 12·50 | − 26·73 | − 39·23 |
| " 19 | 51 H. Cephei | − 17·42 | − 26·73 | − 44·15 |
| " 20 | 30 H. Cephei | − 14·31 | − 27·21 | − 41·52 |
| " 20 | 39 H. Camel. | − 19·58 | − 27·21 | − 46·79 |
| " 20 | α Ursæ Min. | − 12.36 | − 27·21 | − 39·57 |
| " 20 | δ " " | − 13·35 | − 27·21 | − 40·56 |
| " 20 | 76 Draconis | − 13·51 | − 27·21 | − 40·72 |

Mean − 42″·37

Mark south of observatory.

Azimuth of mark from direct observations 179° 59′ 17″·63 ± ″·38,

Azimuth of mark from time sets 179° 59′ 17″·36

HAZELTON, B.C. F. A. McDIARMID, Observer.

| Date | Star | Azimuth of Collimation | Reading on Mark | Azimuth of Mark |
|---|---|---|---|---|
| 1911 | | ° ′ ″ | ″ | ° ′ ″ |
| June 11 | ε Ursæ Min. | 359 59 56·82 | 01·61 | 179 59 58·43 |
| " 12 | α " " | 359 59 56·84 | 01·61 | 179 59 58·45 |
| " 15 | α " " | 359 59 57·29 | 02·99 | 179 59 60·28 |
| " 16 | ε " " | 359 59 54·94 | 03·02 | 179 59 57·96 |
| " 16 | δ " " | 359 59 55·66 | 93·02 | 179 59 58·68 |

Mean 179° 59′ 58″76

Mark south of observatory.

Azimuth of mark from direct observations 179° 59′ 58″·76

Azimuth of mark from time sets 179° 59′ 58″·37

ATLIN, B.C. F. A. McDIARMID, Observer.

| Date | | Star | Azimuth of Collimation | Reading on Mark | Azimuth of Mark |
|---|---|---|---|---|---|
| | | | " | " | ° ′ " |
| 1911 | | | | | |
| June | 30 | α Ursæ Minoris | − 12·83 | 54·81 | 0 00 41·98 |
| " | 30 | ε " " | − 16·43 | 54·81 | 38·38 |
| " | 30 | Groombridge 944 | − 15·93 | 54·81 | 38·88 |
| " | 30 | δ Ursæ Minoris | − 15·94 | 54·81 | 38·87 |
| July | 4 | α " " | − 12·17 | 54·51 | 42·34 |
| " | 5 | Groombridge 944 | − 15·83 | 54·17 | 38·34 |
| " | 5 | δ Ursæ Minoris | − 14·23 | 54·17 | 39·94 |
| " | 5 | 76 Draconis | − 14·04 | 54·17 | 40·13 |
| " | 6 | δ Ursæ Minoris | − 14·64 | 54·46 | 39·82 |
| " | 6 | 51 H. Cephei | − 16·11 | 54·46 | 38·35 |
| " | 6 | 76 Draconis | − 15·25 | 54·46 | 39·21 |
| " | 6 | I. H. Draconis | − 14·98 | 54·46 | 39·48 |
| " | 7 | εUrsæ Minoris | − 14·36 | 54·40 | 40·04 |
| " | 7 | Groombridge 944 | − 13·05 | 54·40 | 41·35 |
| " | 7 | δ Ursæ Minoris | − 14·28 | 54·40 | 40·12 |
| " | 7 | 51 H. Cephei | − 13·35 | 54·40 | 41·05 |
| " | 7 | 76 Draconis | − 11·93 | 54·40 | 42·47 |
| " | 7 | I. H. Draconis | − 15·39 | 54·40 | 39·01 |
| " | 10 | α Ursæ Minoris | − 10·37 | 53·18 | 42·81 |
| " | 10 | ε " " | − 11·75 | 53·18 | 41·43 |
| " | 10 | δ " " | − 11·62 | 53·18 | 41·56 |
| " | 13 | α " " | − 13·31 | 53·32 | 40·01 |
| " | 14 | α " " | − 10.11 | 53·32 | 43·21 |
| " | 14 | ε " " | − 12·07 | 53·32 | 41·25 |
| " | 14 | δ " " | − 12·64 | 53·32 | 40·68 |
| " | 15 | ε " " | − 12·30 | 53·10 | 40·80 |
| " | 16 | ε " " | − 10·84 | 53·25 | 42·41 |
| " | 17 | ε " " | − 10·03 | 53·41 | 43·38 |
| " | 18 | ε " " | − 10·77 | 53·95 | 43·18 |
| " | 20 | α " " | − 11·69 | 53·18 | 41·49 |
| " | 20 | ε " " | − 10·38 | 53·18 | 42·80 |

Mean 0° 0′ 40″·81,

Azimuth of mark from direct observations 0° 0′ 40″·81

Azimuth of mark from time sets 0° 0′ 41″·46

The following Table shows the groupings of the several Atlin observations on each star day by day.

| Star | June 30 | July 4 | July 5 | July 6 | July 7 | July 10 | July 13 | July 14 | July 15 | July 16 | July 17 | July 18 | July 20 | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ |
| U. M. | 41·48 | 42·34 | | | | 42·71 | 40·01 | 43·21 | | | | | 41·49 | 42·05 |
| U. M. | 38·38 | | | | 40·04 | 41·43 | | 41·25 | 40·80 | 42·41 | 43·38 | 43·18 | 42·80 | 41·49 |
| Gr. 944 | 38·88 | | 38·34 | | 41·35 | | | | | | | | | 39·55 |
| U. M. | 38·87 | | 39·94 | 39·82 | 40·12 | 40·56 | | 40·68 | | | | | | 40·10 |
| 76 Dr. | | | 40·13 | 39·21 | 42·47 | | | | | | | | | 40·60 |
| 51 H.C. | | | | 38·35 | 41·05 | | | | | | | | | 39·70 |
| I. H. D. | | | | 39·48 | 39·01 | | | | | | | | | 39·25 |
| Mean | 39·53 | 42·34 | 39·34 | 39·22 | 40·67 | 41·90 | 40·01 | 41·71 | 40·80 | 42·41 | 43·38 | 43·18 | 42·15 | |

An examination of the boundary azimuth results will show that F. A. McDiarmid's six observations on April 30th give an azimuth of 1″·55, and the six observations on May 2nd give 1″·96, and G. C. Baldwin's five observations on May 1st give 3″·00, three on May 8th give 4″·21, and four on May 14th give 1″·24.

The Coutts observations grouped by nights are as follows :

| Date | Azimuth | | | Number of sets |
|---|---|---|---|---|
| | ° | ′ | ″ | |
| August 25 | 359 | 59 | 32·55 | 7 sets |
| " 29 | 359 | 59 | 33·55 | 2 sets |
| Sept. 2 | 359 | 59 | 32·28 | 8 sets |
| " 4 | 359 | 59 | 32·04 | 3 sets |
| " 9 | 359 | 59 | 33·44 | 4 sets |
| " 11 | 359 | 59 | 31·87 | 2 sets |

The observations at Emerson grouped by nights give the following results :—

| Date | Azimuth | | |
|---|---|---|---|
| | ° | ′ | ″ |
| Sept. 17 | 179 | 59 | 15·63 |
| " 18 | 179 | 59 | 19·96 |
| " 19 | 179 | 59 | 18·42 |
| " 20 | 179 | 59 | 18·17 |

A consideration of all these observations leads to the conclusion that there is some error peculiar to each night. What that error is, or what is the cause of it, it is impossible to determine. The explanation usually given is that lateral refraction displaces the mark or star different amounts on different nights. Therefore to insure great accuracy in azimuth determination it is better to increase the number of nights than the number of observations on the same night.

The errors arising from faulty declinations and right ascensions of the stars must be small indeed, as the places of all the stars used are well defined by many observations at the fixed observatories. If the observation is made at or near elongation, the only source of error is from inaccurate declinations or poorly determined latitude; and if the observations are made at or near culmination the errors arise from errors in the right ascension. If the star is observed at both upper and lower culmination any errors of azimuth in the separate observations due to errors in right ascension or time will disappear entirely in the mean.

The observer's personal errors are errors of pointing upon the star or mark, errors of reading graduations if a horizontal circle is used, errors in estimating times of pointing and errors in reading micrometer and level. With an experienced observer the errors of setting will be constant and in the same direction either right or left of the object, and so will have little effect on the azimuth. The azimuth observations of 1910 and 1911 were made at culmination, the programme being to read on the mark, read on the level, observe the transit of a polar star over the whole or part of a comb, reverse the instrument, observe the star over the same part of the field as before, read the level, and again read on the mark. Often both sets of readings on the mark were made either before or after the star observations. The instrument was mounted so rigidly that no fixed variation was discernible in the different readings on the mark during a night; and, indeed, the mark readings from night to night were very similar, showing that the change in azimuth of the instrument was small indeed. There follows below a list of values of the angle between the line of collimation, and the line from the instrument to the mark, on two different nights.

| Date | Time | Angle between line of Collimation and line to mark |
|---|---|---|
| 1910 | h m | " |
| August 25 | 19 58 | 23·78 |
| | 20 25 | 23·53 |
| | 21 08 | 22·48 |
| | 21 40 | 23·11 |
| | 22 06 | 22·86 |
| | 22 42 | 22·97 |

| Date | Time | | Angle between lines of Collimation and line to mark |
|---|---|---|---|
| 1910 | h | m | " |
| July 12 | 16 | 48 | 02·89 |
| | 18 | 10 | 02·75 |
| | 19 | 17 | 02·99 |
| | 20 | 50 | 03·54 |
| | 21 | 24 | 02·74 |
| | 22 | 15 | 02·92 |

Any differences in the angle between the line of collimation and the line to the mark in the above examples may safely be attributed to errors of observation, and so the mean of all the readings for a night was taken as the value of the angle for that night.

As the star observations were recorded on a chronograph, the errors of reading micrometer and estimating fractions of a second were entirely obliterated. From an examination of several sets of micrometer readings on the mark, the probable error of a single setting was found to be about ± "·30 ; and the probable error of the mean of ten settings was ± "·095.

The only other personal error that enters into the work is the bisection error. If it can be assumed that the error of setting on a mark is the same as the error of setting on a star, then the bisection error has no effect on the azimuth. But some uncertainty may exist as to whether bisecting a mark is the same as bisecting a moving object such as a star. It was the intention to make some observations for bisection error during the season of 1910, but the weather conditions were so poor all season that all the good weather available was required for the regular observations. However, in Ottawa during the winter of 1910-11, a few observations were made to determine, if possible, the effect of bisection error on an azimuth observation. Four polars were observed over the outside combs of the transit with the eye piece at right angles to the direction of motion of the star image, and over the inside combs with the eye piece at 45° to the vertical. The first and fourth observations were taken with the eye piece in the same position ; the second was taken with the eye piece at 45° to the left, and the third with the eye piece at 45° to the right. In both the second and third observations the star appears to move vertically, but in opposite directions thereby removing from the mean any errors of bisection. In the following table appear the results.

| Star | Azimuth, Eye Piece Vertical | Azimuth, Eye Piece at 45° |
|---|---|---|
| | ° ′ ″ | ° ′ ″ |
| (1) Gr. 947 | 0 0 08·00 | 0 0 09·73 |
| (2) Gr. 750 | 08·96 | 08·53 |
| (3) Gr. 2283 | 08·94 | 09·87 |
| (4) Gr. 2750 | 09·30 | 08·94 |
| Mean | 0 0 08·80 | 0 0 09·27 |

It will be seen on comparing the above results that the difference is not more than can be attributed to errors of observation. The differences between the two observations in (1) and (3) are of opposite signs to those in (2) and (4). It would therefore seem that any errors in azimuth due to faulty bisections are of small dimensions.

A comparison of the observations of stars at upper and lower culmination at North Portal, Coutts and Emerson shows little difference in the azimuth results.

| Station | Azimuth from Upper Culmination | Azimuth from Lower Culmination |
|---|---|---|
| | ° ′ ″ | ° ′ ″ |
| North Portal | 359 59 50·54 | 359 59 50·15 |
| Coutts | 359 59 32·77 | 359 59 32·45 |
| Emerson | 179 59 17·70 | 179 59 17·57 |

The differences are ″·39, ″·32 and ″·13, but with so few observations it is impossible to say whether they are due to errors of setting, or are accidental.

A comparison of the azimuth determinations from time sets and by direct observations shows that a very good azimuth result is derived from our time sets as at present constituted. The following table gives a comparison of the azimuths obtained in the two ways.

| Station | Azimuth from Direct Observation | | | Azimuth from Time Sets | | |
|---|---|---|---|---|---|---|
| | ° | ′ | ″ | ° | ′ | ″ |
| North Portal | 359 | 59 | 50·37 | 359 | 59 | 50·89 |
| Coutts | 359 | 59 | 32·61 | 359 | 59 | 32·30 |
| Emerson | 179 | 59 | 17·63 | 179 | 59 | 17·36 |
| Hazelton | 179 | 59 | 58·76 | 179 | 59 | 58·37 |
| Atlin | 0 | 0 | 40·81 | 0 | 0 | 41·46 |

The method of observing azimuth with the transit instrument in the meridian is not generally used, but the results obtained speak well for it. The average probable error obtained under favorable conditions was about ± ″·20 at Coutts, North Portal, Atlin, and Hazelton. From the work done on the Mexican boundary by the United States Coast and Geodetic survey the average probable error was about ± ″·28. There were probably more observations taken on the Canadian work than on the Mexican boundary work, and consequently a smaller probable error would be expected; but the results show at least as great a degree of accuracy with the method used at the stations mentioned above as that obtained on the Mexican boundary. In the latter work the observations were all made on Polaris near elongation, while in the Canadian work any star of declination greater than 82° was used at either upper or lower culmination. The observations are all recorded on the chronograph, and the collimation error is entirely wiped out by reversing the instrument between the two observations on the star. The azimuth observations were made on the same nights as the longitude and latitdue observations. By so doing a great amount of time was saved, but the results no doubt would have been better if the observer had confined himself to one kind of work on a single night. However, with cloudy weather, smoky nights, uncertain telegraph connections to overcome, the field observer is glad to put in long hours on every clear night. The large probable error at Emerson is attributed largely to lateral refraction. Emerson is in a very level district, and at the time of observation the farmers were engaged at their fall ploughing. The azimuth line passed a few feet (about three) above a freshly ploughed field, and so uncertain readings might be expected. Conditions might even change sufficiently during a single night to account for a good part of the residuals in this work.

With our instrument as at present constituted, it is necessary to have the azimuth mark nearly in the meridian of the observer. If an instrument were devised with a horizontal circle and so arranged as to reverse the telescope in the wyes, then the mark need not be in the meridian, but may be in any direction whatever. With an instrument so constructed it would only be necessary to make one reading of the horizontal circle on mark and star. In the ordinary micrometer-direction method it is necessary to read the horizontal circle with vertical circle both right and left. The great difficulty in the manufacture of such an instrument would be to have it sufficiently rigid and stable to permit of reversal without in the slightest degree jaring the instrument, or altering the readings of the horizontal circle. However, observations can always be taken on a mark in the meridian, and the azimuth line connected with the triangulation or survey.

Dominion Observatory,
Ottawa, Canada.

# PERSEIDS AND LEONIDS

BY W. F. DENNING

THESE form the two great meteoric showers of the year. Famed in history, familiar to all observing astronomers and fraught with interesting associations, they are invariably watched with enthusiasm. Yet they are utterly dissimilar in character.

The Perseids come every year in moderate intensity and endure for the long period of six weeks, July 15 to August 25.

The Leonids appear in great strength for a few hours at intervals of about 33⅓ years, but are presented in numbers only equivalent to a minor shower at most returns, though seldom if ever entirely missing.

When the Leonids assume their most abundant aspect they form the grandest celestial spectacle of a generation as in 1799, 1833 and 1867. But the expected fine apparitions of 1899 and 1900 failed, the swarm having been drawn away from the earth by the attraction of the major planets, Jupiter and Saturn.

Which of the two showers is entitled to be considered the more important? Each has told its own engrossing story. But the Perseid swarm has many claims to precedence. It never fails to embellish our summer skies with brilliant shooting stars. In July as well as in August they are showered into the earth's atmosphere and about sixty or seventy millions of these fiery visitors are consumed at every return.

Yet there is no apparent diminution in the strength of the display, nor is it likely that any decline in numbers will become noticeable, for it has been calculated that 300,000,000,000,000 fragments must compose the entire stream.

The Leonids only visit us on the cold damp mornings of November, and in full plentitude and brilliancy only once in an extended series of years. On frequent occasions they are apt to prove disappointing and cannot be seen at all in England until a late hour of the night as their radiant does not rise in the E. N. E. before 10.15 p.m.

The Perseids are always true to time and place. They are visible at any hour of the night. They come as sure as the darker evenings of August and formerly exhibited great abundance on St. Lawrence Day, August 10, but there having been no leap year in 1900 they now appear a day or two later than that anniversary.

As an old meteoric observer, who witnessed the great Leonid display of 1866 and who is still watching meteors to-day, let me say that I esteem the Perseids as essentially the chief meteoric phenomenon of the year. Regular in its returns and fairly rich in its exhibitions, it may be traced amid all the delightful surroundings of genial evenings in the holiday season. The Leonids have sometimes far eclipsed it in interest, I know, and there have been years in which men talked only of the November meteors, as though the August Perseids had little share in the making of meteoric history.

And, truth to tell, there is something singularly impressive in these blazing Leonid messengers on a keen November morning. There is frost in the air, the stars sparkle brilliantly, all is still, while high in the south-east the stars of Leo distribute their shafts of wavering light to all parts of the firmament. The scene is striking, for the imagination finds it easy to impart a threatening aspect to the Sickle of the Lion as it fitfully bombards our terrestrial atmosphere with possibly dangerous intent. Not so the August shower, sprinkled from a position near the amiable lady reclining peacefully in the chair of Cassiopeia.

These meteors have a more harmless look and may be likened to glow-worms flying high along the genial zephyrs of the summer season.

The following are some particulars concerning the two streams :—

| | Perseids | Leonids |
|---|---|---|
| Date of maximum display | August 11 | November 15 |
| Duration | July 15-Aug. 25 | November 7-20? |
| Period | 105 years? | 33⅓ years |
| Parent Comet | 1862 III. | 1866 I. |
| Period | 123·4 years? | 33·176 years |
| Radiant Point of Comet | 43°·5 +57°·4 | 150°·5 +23° |
| Radiant Point of Meteoric Shower | 44 +57 | 150 +23 |
| Height of Meteors at beginning | 81·2 miles | 82·7 miles |
| Height of Meteors at ending | 53·4 miles | 55·7 miles |
| Length of Flight | 47·8 miles | 54·1 miles |
| Observed Velocity | 38·8 miles | 47·9 miles |
| Theoretical Velocity | 38 miles | 44 miles |
| First Historical Record of Shower | July, A.D. 811 | October, A.D. 902 |

Many persons have been rather disappointed in recent years on looking out on August 10 and finding few meteors visible. The fact is that the best night is now usually the 11th or 12th. The date advances slowly with the time; thus the date of the shower in A.D. 811 was July 25, so that it gets about one day forward in a century.

This year there were a fair number of meteors visible on August 11 and 12 but comparatively few on August 10. There was a large proportion of brilliant objects and many of them having been recorded at several stations will be subjected to further discussion and their real paths computed. The radiant showed the usual displacement to the eastwards. The first oncoming members of the display were remarked on July 14 and the latest traces of the display were visible on August 20. Cloudy weather has, however, interfered, as it always does, with the perfectly satisfactory tracing of the shower's progress from night to night.

In recent years very few Leonids have been visible. There have been, however, a few stray shots from the Sickle of Leo at the middle of November and these have sufficiently proved the continued activity of the stream though under a meagre aspect. The shower should be carefully observed every year and its varying strength recorded. This also applies to another strong but irregular display from Andromeda and connected with Biela's lost comet. It was distinctly visible in 1913, November 18-21, when I observed nine of its slow meteors form a radiant 27° +42°. I have always found this radiant apparently spread over a large area and it is difficult to get the centre accurately.

BRISTOL, ENGLAND,
August 25, 1914.

PLATE VIII.

PHOTOGRAPHS OF LIGHTNING

Taken at Ottawa, July 10, 1914. By A. Steadworthy. (See page 345).

PLATE IX.

PHOTOGRAPHS OF LIGHTNING

Taken at Ottawa, July 10, 1914. By A. Steadworthy.

*Journal of the Royal Astronomical Society of Canada, 1914*

# SPECTRUM OF LIGHTNING

By A. Steadworthy

HAVING for some years photographed lightning at night, and having been successful in photographing lightning in broad daylight, (*vide* Journal of the Royal Astronomical Society of Canada for November-December, 1912,) I determined to secure a spectrum of lightning.

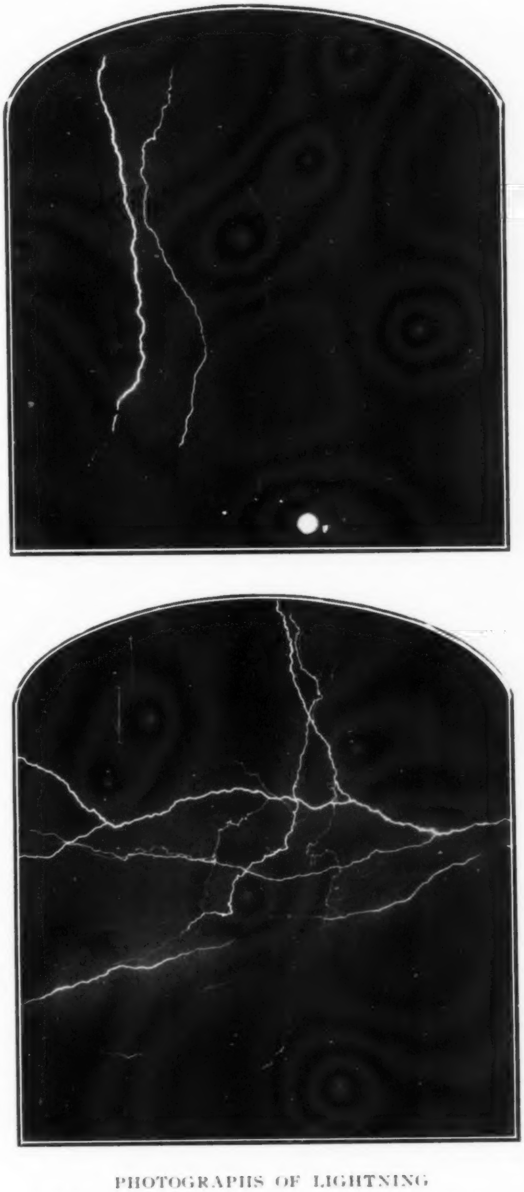
A favorable opportunity offered on the night of July 10th last, when a storm began to develop at 6 p.m. at Ottawa in the west. Low lying cumulus clouds slowly spread towards the north and south where distant lightning first manifested itself. The clouds, becoming denser and denser, approached Ottawa and slowly rose above the horizon. By 7 p.m. the first rumblings of thunder began, and by 9.30 p.m. the pyrotechnic display in the west became so vivid that I brought out the two cameras which I had in readiness at my house overlooking McDonald Park, giving me an outlook from the west through the north to the east. One camera was fitted with stereoscopic lenses, the other was an 8 in. x 10 in. camera with 2 in. lens, 16 in. focus. In front of it was fitted in a box one of our 60° dense flint glass objective prisms. The box could be rotated on the collar of the lens, thereby enabling spectra to be obtained over a range of 180° without moving the camera. It must be observed here that the size of the small box and the prism not physically covering the lens made it possible for a flash coming from a certain direction to get through the lens and onto the plate without passing through the prism. And this is exactly what happened, as seen on Plate XI., which shows the spectrum secured with the superimposed other flash.

I made four exposures on Cramer isochromatic plates, for, as I thought, four spectra. One of the plates turned out a blank, one showed a very weak spectrum, one showed the fine spectrum on the above plate, while the last showed remarkable dotted curved lines, one at the top of the plate and several parallel ones below. I utterly fail to divine their origin. The exposure and the position of the camera were identical in the two cases. None of the other three plates shows this phenomenon.

As stated, I was busy with both cameras, securing some ten fine stereoscopic photographs of lightning (Plates VIII., XI., X.) besides the spectrum. The time was approximately between 10 and 10.30 p.m. For the spectrum I knew that it was desirable to have an intense flash not very distant, and hence abided my time watching the motion of the storm. I estimated the distance by sound of the flash giving the spectrum to have been half a mile. My time was very much occupied, and with so many flashes and the almost constant roar of thunder, an accurate determination of the distance was impossible. The lightning, however, was very close. During all this time no rain was falling. Suddenly, about 10.30 p.m., there was a swish and whirring through the air and trees, and the next moment a torrential rain descended. It came so suddenly that I scarcely had time to save the cameras from being blown away, and to find shelter in the house from the verandah at the second story where I was stationed. I may say that later, 11 p.m., I took a stereo from an open window looking south, while a heavy rain *was falling*, and strange to say this shows the houses almost as distinctly as if taken in day-light.

The following measurements of the lines of the spectrum (See Plate XII.) have been made by Mr. J. B. Cannon, of the Observatory, who adds the accompanying note.

PLATE X.



PHOTOGRAPHS OF LIGHTNING

Taken at Ottawa, July 10, 1914. By A. Steadworthy.

PLATE XI.

SPECTRUM OF LIGHTNING

Photographed at Ottawa, by A. Steadworthy, July 10, 1914. (See page 345).
The straight streaks at the bottom are spectra of street lamps.

LINES IN SPECTRUM OF LIGHTNING

| Wave-Length | Character | Fox's Wave-Length[1] | |
|---|---|---|---|
| 5683* | strong, well defined line | 5683 | r. edge |
| 5618·3 | broad | 5600 | max. |
| 5550·3 | broad and strong | | |
| 5423·2 | violet edge of gradually fading band | | |
| | | | |
| 5345·5 | faint, broad band | 5305 | v. edge |
| 5180·9 | faint, broad line | 5175 | |
| 5003·7* | good, strong band | 5003·7 | |
| 4928·5 | faint line | | |
| 4852·4 | broad, fairly strong band | 4842 | |
| 4800·7 | faint line | 4785 | |
| | | | |
| 4680·5 | fairly good line | 4660 | r. edge |
| | faint indistinct lines between 4688·5 and 4648·9 | | |
| 4648·9 | faint line | | |
| 4635·6 | strong, clear line | 4630·7 | |
| | more faint lines | | |
| 4605·3 | fairly strong broad lines | 4603 | v. edge |
| | | | |
| 4542·8 | faint line | 4535 | |
| | | | |
| 4522·8 | fairly strong line | | |
| | | | |
| 4483·8 | a pair of rather weak lines, v. one the stronger | | |
| 4468·6 | | | |
| | | | |
| 4442·5 | strong, clear line | 4439 | |
| 4427·8 | line fainter and broader | | |
| 4413·4 | very faint line | | |
| | | | |
| 4367·9 | strong line | 4359 | |
| 4354·3 | line less strong | | |
| 4340·9 | fainter, broad line | | |
| | | | |
| 4308·1 | faint, broad band | | |
| 4270·2 | very faint | | |
| 4264·1 | very faint | | |
| | | | |
| 4251·9 | faint line | | |
| 4239·8 | strong line | 4238 | |
| 4217·7 | strong, clear line | | |
| 4210·1 | faint line | | |
| | | | |
| 4190·1 | very faint line | 4183 | |
| 4170·4 | fairly strong line | | |
| | | | |
| 4151·2 | good, strong line | 4154 | |
| 4143·1 | good, line not so strong as 4151 | | |
| | | | |
| 4127·0 | very faint line | | |

LINES IN SPECTRUM OF LIGHTNING—(*Continued*)

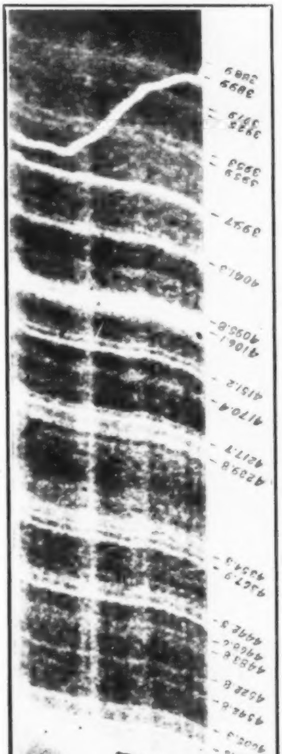
| Wave-Length | Character | Fox's Wave-Length |
|---|---|---|
| { 4106·1<br>{ 4095·8 | very strong line, forms a close strong pair with 4095·8 | 4105 |
| 4070·6 | rather faint line | 4077 |
| 4041·3 | good, strong line | 4041·5 |
| 4036·5 | faint line | |
| 4024·7 | faint line | |
| 4015·3 | faint line | |
| 3997* | good, strong line | 3997 |
| { 3959·2<br>{ 3952·7 | faint pair of lines | 3943 |
| { 3925·2<br>{ 3919·0 | faint pair of lines | 3915 |
| 3898·7 | faint line | 3890 |
| 3888·7 | very faint | 3838 |

* Lines marked thus were used as standards in the computation of wave-lengths.

[1]Column 3 contains the wave-lengths given by Fox in the *Astrophysical Journal*, XVIII., page 205. The figures here are those given under the heading "low power."

DOMINION OBSERVATORY,
OTTAWA, CANADA,
September, 1914

PLATE XII.



SPECTRUM OF LIGHTNING

A portion of Plate XI, with wave-lengths added. (Magnified 5 times original).

# THE METEOR-FALL OF ENSISHEIM (1492)

By C. A. Chant

WHILE reading the printer's proofs of the article on "Meteorites" by Mr. H. B. Collier, which appeared in a recent number of this JOURNAL,* it occurred to me to verify some of the historical statements in it, by reference to works which were at my hand; and I was surprised to find considerable discrepancies between different authorities. This was especially so in the case of the famous meteorite which fell at Ensisheim, in Alsace, 1492.

A somewhat extended account of the occurrence is given in Chambers's "Handbook of Astronomy,"† and in Ball's "Story of the Heavens."‡ Chambers states that the narrative he gives was drawn up at the time by order of the Emperor Maximilian, and deposited with the fallen stone in the church at Ensisheim; but the two printed accounts, though identical in the main, differ in some particulars.

Following is the statement as presented by Chambers, but in those places where Ball's version differs from it, the latter is given in brackets.

"In the year of the Lord 1492, on Wednesday, which was Martinmas Eve, [on the Wednesday before St. Martin's Day,] November 7th, a singular miracle occurred; for between 11 o'clock and noon there was a loud clap of thunder, and a prolonged confused noise, which was heard at a great distance; and a stone fell from the air, in the jurisdiction of Ensisheim, which weighed 260 pounds; and the confused noise was, moreover, [at other places] much louder than here. There a child saw it strike on a field [on ploughed ground] in the upper jurisdiction, [field] towards the Rhine and Jura, [the Ill] near the district of Giscano, [Gisgang] which was sown with wheat, and it did no harm, except that it made a hole there;

* Vol. VII., p. 313 (September October) 1913.

† Vol. I., p. 594 (4th ed.).

‡ Page 352, 4th ed., 1888.

and then they conveyed it from that spot, and many pieces were broken from it, which the landvogt forbade. They therefore caused it to be placed in the church, with the intention of suspending it as a miracle; and there came here many people to see this stone. So there were remarkable conversations about this stone; but the learned said they knew not what it was; for it was beyond the ordinary course of nature that such a large stone should smite the earth, [omit 'the earth'] from the height of the air, but that it really was a miracle of God; for, before that time, never anything was heard like it, nor seen, nor described. When they found that stone, it had entered into the earth to the depth [to half the depth] of a man's stature, which everybody explained to be the will of God that it should be found: and the noise of it was heard at Lucerne, at Vitting, [Villingen] and in many other places, so loud, that it was believed that houses had been overturned; and as the King Maximilian was here the Monday after St. Catherine's Day of the same year, His Royal Excellency ordered the stone which had fallen to be brought to the castle; and after having conversed a long time about it with the noblemen, he said that the people of Ensisheim should take it, and order it to be hung up in the church, and not to allow anybody to take anything from it. His Excellency, however, took two pieces of it, of which he kept one, and sent the other to Duke Sigismund of Austria; and they spoke a great deal about this stone, which they suspended in the choir, where it still is; and a great many people came to see it."

A copy of the original German inscription which hung under the stone in the church at Ensisheim for some time is to be found in Gilbert's *Annalen*, vol. 18, p. 280-281, 1804. The text as there given was supplied by Hofrath Blumenbach, and it is as follows:—

A.D. 1492 uff Mittwochen nechst vor Martini den 7ten Tag Novembris geschah ein seltsam Wunderzeichen; denn zwischen der eilfften und zwölften Stund zu Mittagzeit kam ein grosser Donderklapff und ein lang Getöss, welches man weit und breit hört, und fiel ein Stein von den Lüften herab bei Ensisheim in ihrem Bann, der wog zwei hundert und sechzig Pfund, und war der Klopff anders wo viel grösser dann allhier: Da sahe ihn ein Knabe in eim Acker im obern Felde, so gegen Rhein und Ill zeucht, bei dem Gisgang gelegen, schlägen, der war mit Waitzen gesäet, und that ihm kein Schaden als dass ein Loch innen würd. Da führten sie ihn hinweg, und ward mannich Stück davon geschlagen: das verbot der Landvogt; Also liess man ihn in die Kirche legen, ihn willens dann zu einem Wunder aufzuhenken, und kamen viel Leut allher den Stein zu sehen, auch wurden viel seltsame Reden von dem Stein geredet. Aber die Gelehrten sagten sie wissen nicht was es wär, denn es wär übernatürlich dass ein solcher Stein sollt von ben Lüfften herab schlagen, besonders es wäre ein Wunder Gottes, denn es zuvor nie erhört, gesehen noch geschrieben befunden worden wäre. Da man auch den

Stein fand, da lag er bey halb Manns tief in der Erden, welches jedermann dafür hält dass es Gottes Wille wär, dass er gefunden würde. Und hat man den Klopff zu Lucern, zu Pfillingen und sonst an viel Orten so gross gehört dass die Leut meynten es wären Häuser umgefallen. Darnach uf Montag nach Catharinen gedachten Jahrs als König Maximilian allhier war, hiess ihre königl. Excellenz den Stein so jüngst gefallen, ins Schloss tragen, und als man ihn dahin brachte, hielt er Excellenz viel Kurzweil mit dem Stein, und da er lang mit den Herrn davon geredt, sagte er die von Ensisheim sollten ihn nehmen und in die Kirche heissen aufhencken, auch niemands davon lassen schlagen. Doch nahm er Excellenz zwey stück davon: das Eine behielt sein Excellenz; das Andere schickte er Herzog Sigmunden von Oesterreich, und war eine grosse Sage von dem Stein, also hinck man ihn in den Chor da er noch henckt. Auch kam eine grosse Welt den Stein zu sehen.

A comparion of this with the above translation will show that Ball's version is the more accurate.

This same narrative is given in condensed form by Fletcher in his "Introduction to the Study of Meteorites" * on page 19, but he gives the date as November 16, and states that the stone fell "in a field near the canton called Gisgaud, where it made a hole more than five feet deep."

In the article "Meteorite" in the "Encyclopedia Britannica," 11th ed., volume XVIII., p. 262 (written by Fletcher) the date is given as November 10. This is probably a misprint for 16.

Kirkwood in "Comets and Meteors," (Philadephia, 1873,) p. 59, gives November 7 as the date, states that the aerolite weighed 276 pounds and that it penetrated the earth to a distance of three feet.

Flammarion, in his "Popular Astronomy" (translated by Gore), gives the date as November 7, the weight as 158 kg. = 348 lbs.; and says, further, that the stone was first placed in the church, but that now it is in the mineralogical museum of Vienna.

Before going further it may be stated that November 7, old style, is the same as November 16, new style, which accounts for the apparent difference in dates; also November 7, 1492, fell on Wednesday. Martinmas was a festival in honor of St. Martin of

*L. Fletcher, M.A., F.R.S., is keeper of Minerals in the British Museum; this small volume is one of the admirable guide.books to that institution.

France, celebrated on November 11, which in 1492 fell on Sunday.

Turning now to Wülfing's encyclopedic work entitled, "Meteoriten in Sammlungen und ihre Literatur" (1897), I find over two pages of references to various published articles relating to this famous meteorite, together with a list of 65 museums possessing portions of it. The original weight is given as about 127 kg. = 279 lbs., of which, 70·4 kg. can now be located. Of this, 54·8 kg. is preserved in the town-hall at Ensisheim.

The literature on the subject is arranged by Wülfing in chronological order and the earliest publication bears date 1492. It is a folio-sheet, printed on one side only, and contains a Latin poem by Sebastian Brant, the author of "Das Narrenschiff," (1494) or "The Ship of Fools," a work of great importance in the history of both German and English literature. On the sheet is also in German a version of the occurrence, ending with an admonition to King Maximilian, who at that time was with an army in Alsace. Under the German title and above the address to Maximilian is a wood-cut representing the fall of the meteoric stone. A copy of this sheet is in the university library at Basel, Switzerland.* In 1492 Brant was Dean of the Faculty of Law in this university.

The contents of this sheet are reprinted in Poggendorff's *Annalen*, vol. 122, p. 182, 1864; and I thought it of sufficient interest to reproduce it here.

First of all, I give the Latin text. With the aid of my colleagues, Professors Fletcher and Carruthers, of the Department of Classics, the real meaning of the somewhat obscure Latin was obtained; and my friend Dr. A. D. Watson then put the translation into English verse. He insists that he would hardly call it poetry, but I venture to think it quite as good poetry as the original. The German version is not reproduced here, but I am able to present a translation of it in flowing English by my colleague, Professor A. E. Lang.

* The writer had hoped to reproduce this sheet in fac simile in the JOURNAL, but the photographic copy of it which had been promised has not yet been received.

## DE FULGETRA ANNI XCII

### Sebastianus Brant

Perlegat antiquis miracula facta sub annis
  Qui volet : et nostros comparet inde dies.
Visa licet fuerint portenta, horrendaque monstra
  Lucere e celo : flamma, corona, trabes,
Astra diurna, faces, tremor et telluris hyatus
  Et bolides. Typhon, sanguineusque polus.
Circulus : et lumen nocturno tempore visum.
  Ardentes clypei et, nubigeneque fere.
Montibus et visi quondam concurrere montes
  Armorum et crepitus, et tuba terribilis.
Lac pluere e celo visum est, frugesque calybsque
  Ferrum etiam, et lateres, et caro, lana, cruor,
Et sexcenta aliis, ostenta ascripta, libellis :
  Prodigiis ausim vix similare novis.
Visio dira quidem Friderici tempore primi
  Et tremor in terris, lunaque, solque triplex.
Hinc cruce signatus Friderico rege secundo
  Excidit inscriptus grammate, ab hymbre lapis.
Austria quem genuit senior Fridericus, in agros
  Tercius hunc proprios : et cadere arva videt.
Nempe quadringentos, plus mille peregerat annos
  Sol noviesque decem signifer, atque duos.
Septem praterea dat idus, metuenda novembris :
  Ad medium cursum tenderat illa dies.
Cum tonat horrendum : crepuitque per aera fulmen
  Multisonum : hic ingens concidit atque lapis.
Cui species delte est, aciesque triangula : obustus
  Est color, et terre forma metalligere.
Missus ab obliquo fertur : visusque sub auris
  Saturni qualem mittere sydus habet.
Senserat hunc Enshein. Suntgaudia sensit : in agros
  Illic insiluit, depopulatus humum.
Qui licet in partes fuerit distractus ubique :
  Pondus adhuc tamen hoc continet, ecce vides.
Quin mirum est potuisse hyemis cecidisse diebus :
  Aut fieri in tanto frigore congeries ?
Et nisi anaxagore referant monimenta : molarem
  Casurum lapidem : credere et ista negem.

Hic tamen auditus fragor undique littore Rheni :
Audiit hunc Uri proximus alpicola :
Norica vallis eum, Suevi, Rhetique stupebant :
Allobroges timeant : Francia certe tremit.
Quicquid id est, magnum portendit (crede) futurum
Omen : at id veniat hostibus oro malis.

---

## THE THUNDERBOLT OF 1492

By Sebastian Brant

English verse by Albert D. Watson

All ye who will may read of fearsome things
And marvellous, of crowns and flaming wings,
Of omens dread, and portent meteors dire,
That blazed the ancient dome with lurid fire ;
When lofty torches dartling arrows down
And fierce-eyed beasts made all the shadows frown.
Day died to blackness, and the night was rent
With lightnings or with mist of stars besprent.
Hark to the trump of terror ! Clang of arms
Rends the bewildered skies with strange alarms,
While down their archways pour in motley flood
Flesh, wool and tiles all mixed with milk and blood.
Horrific noises mark the dreadful clash
Of fiery shields that 'gainst the mountains crash ;
Bright-gleaming shards fall hurtling through the air
And cleave the lurid dark with awful glare.
Earth gapes and trembles : stars are seen by day ;
Midnight is vivid as noon in May.
A thousand volumes scarce the tale could tell
Of all the horrors of that ancient hell.

In recent times, earth trembled in a swoon,
Aghast to view a triple sun and moon.
'Twas in the days of Frederick, named the First,
This prodigy on human vision burst.

In fourteen-ninety-two, a fearful light
Blazed all the heavens and quenched the myriad night.
O'er Frederick Second's lands, they tell,

The awesome thunderbolt, fire-flinging, fell.
At noon, that dread November day, through air
By whirlwinds tempested, 'mid thunder's blare,
Down from the skies was hurled the mighty stone
Signed with a cross in characters unknown.
The younger Frederick, born in Austria, stood,
Beheld its fall — discerned the holy rood —
Its shape triangular on every side,
Its hue as 'twere with deepest umber dyed.
With rattling sound, the ore was sideways hurled
With influence like a great Saturnian world.
The bolt Ensisheim saw, Suntgaudia too,
And still is kept intact for public view.
Since from the skies it fell, its solid state
No heat doth fuse, no cold disintegrate.
This was by Anaxagoras foretold
Else could we not such things with credence hold.
Yet, where the streams the rugged mountains gird,
The rumbling crash in Switzerland was heard:
The Uri people and the Rhineland knew,
The Suabians and the Noric valley too.
Let Allobroges fear it! Tremble France!
These awful portents brood some strange mischance.
Whate'er it be, I pray the blow may fall
Upon our wicked enemies. God save us all!

---

## TRANSLATION OF THE GERMAN VERSION

By A. E. Lang

Many a man marvels at stories from foreign lands.
  Let such an one also read and note this account.
There have been seen many marvels
  In the heavens, comets and fiery darts,
Burning torches, flames and crowns,
  And circles about the moon
In the heavens. Blood and fiery shields,
  Rain fashioned in the form of animals,
Shocks, crackings of heaven and earth
  And many other strange things,
Defiantly two mountains knock themselves to pieces,
  Horrible crash of trumpets and of arms,

Iron, milk, rain, steel, grain,
  Brick, meat, wool, of heaven's anger,
As well as other wonders of that kind.
  Then, in the reign of the first Frederick,
Besides earthquake and darkness,
  One saw three suns and moons.
And under the Emperor Frederick,
  The Second, fell a horrible stone.
Its form was large, and thereon was a cross,
  And other writings and secret sense,
And during the time of the third Frederick,
  Born lord of Austria,
There rises here, in his own land,
  The stone that lies here by the wall.
When they wrote fourteen hundred years,
  On St. Florence Day it was
Ninety and two at noon-day
  There came a dreadful thunder-crash,
Three-hundred weight heavy, fell this stone
  Here in the field before Ensisheim.
Triangular in form and blackened even,
  As though made of mineral and earth,
Also was seen in the air.
  It fell slanting into a cleft in the earth.
Small pieces fell here and there,
  And scattered far, they heard its roar
Even in Tunow, Neckar, Aar, Ill and Rhine,
  Schwiz, Uri, and the Inn hears the clap.
Also the Burgundians hear the report,
  The French feared it much,
And rightly, I say that it betokens
  An especial plague to these people.

---

The second reference to the meteorite is contained in *Liber Cronicarum* ( Book of the Chronicles ) written by a Nuremberg physician named Hartmann Schedel, and first published in Latin in 1493 ; afterwards in German in 1496, at Augsburg.

The part which refers to this event is on leaf 300, page 1, and in English runs as follows : —

Now, as heretofore in many places, many and strange things have been reported as happening in the sky, and especially that a stone marked with a cross had fallen at the time of Emperor Frederick II., so also in the time of the Emperor Frederick III., in the year of Christ our Saviour 1492, on the seventh day of the month of November at noon a large stone of about a hundred-weight and little smaller than a salt-shovel [saltzscheyb], shaped like a Greek Δ and triangular in form, fell down from the sky near the village of Ensisheim in the Suntgew, and, as a witness of the strange event, is still in existence.

For the translation of the old German I have again to thank Professor Lang.

The above was republished in Poggendorff's *Annalen*, vol. 121, p. 333, 1864, and at the time was thought to be the earliest printed record of the phenomenon, but it appears that Brant's verses preceded it.

## NOTES FROM THE METEOROLOGICAL SERVICE

### Summary Report of the Weather in Canada

#### August

*Temperature*.—There were no very wide departures from the normal temperature in any of the Provinces, but, as the month advanced, there was a tendency towards cooler conditions, and the larger portion of all the Provinces, exclusive of Alberta, shewed an average temperature slightly below normal. The largest negative departure was 4° at Qu'Appelle, and the largest positive was 3° at Calgary, Alberta.

*Precipitation*.—The larger part of the Dominion, as in the previous month, again experienced a shortage in rainfall, and this was especially marked in Southern British Columbia, in parts of Southern Alberta and Saskatchewan, and in Northern Ontario and Eastern Quebec. In the Peninsula of Ontario, on the other hand, the rainfall was exceptionally heavy, while in the Southwestern portions of Quebec and the Maritime Provinces, and also in Northern Alberta and Saskatchewan, it was either equal to or slightly exceeded the normal amount.

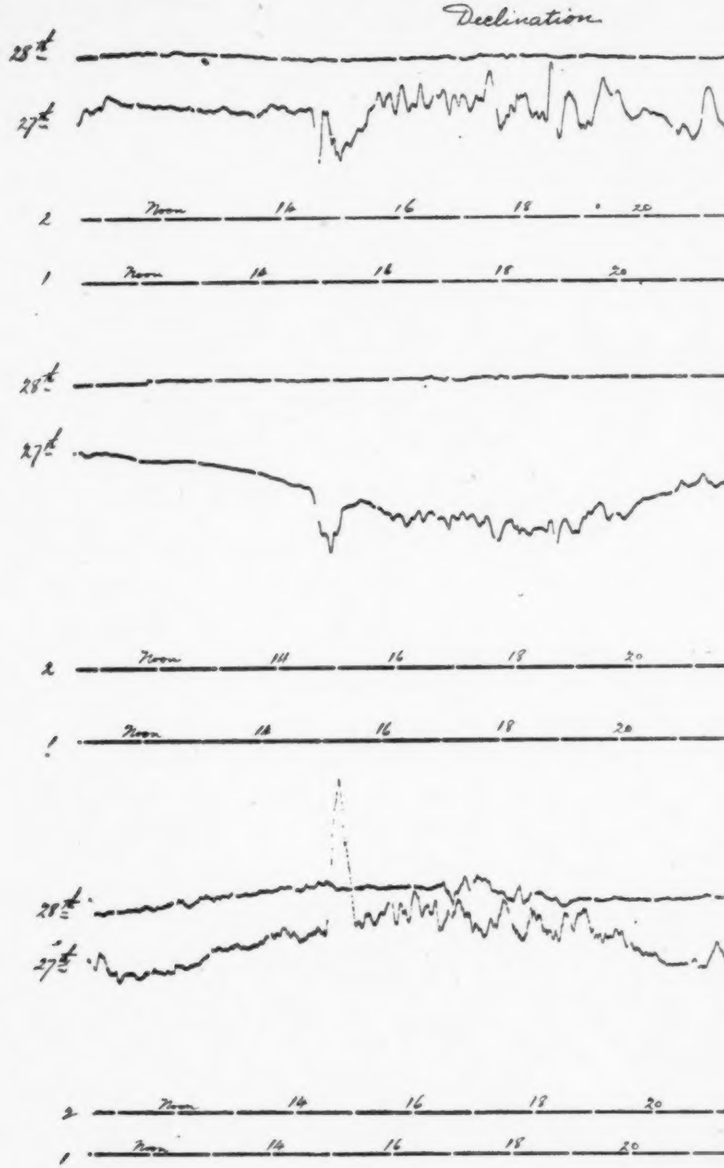
#### September

*Temperature*.—The temperature was above the average from the Rocky Mountains to the western half of Lake Superior, also very locally in Quebec and New Brunswick; elsewhere in the Dominion the average was not, or only barely, maintained. The chief negative departures were 5° at Victoria, and 3° at Port Stanley and Ottawa, and the positive, 4° at Calgary and Minnedosa.

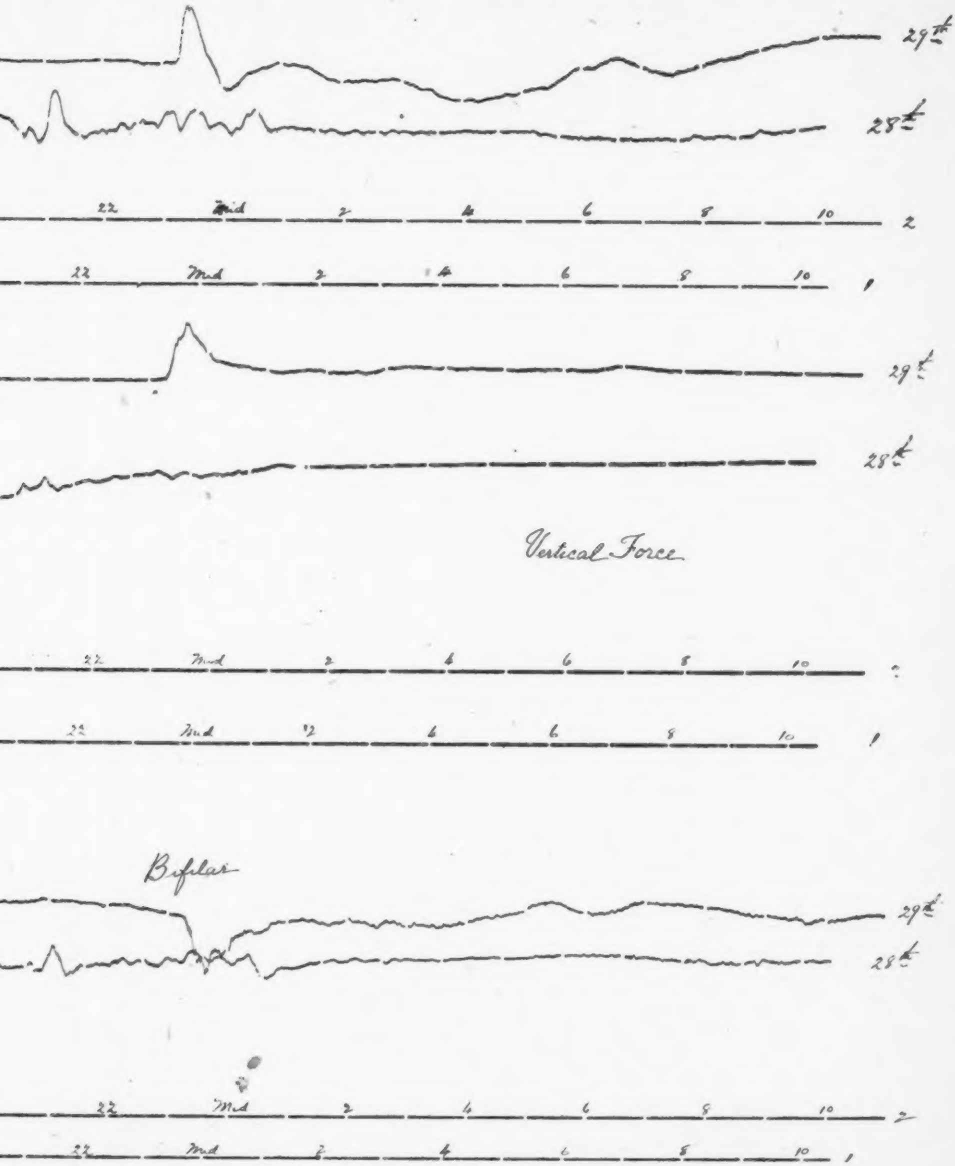
*Precipitation* — A marked feature of the weather of the year up to the end of September has been the deficiency in precipitation in nearly all parts of the Dominion, and particularly so in Southern Alberta and Southwestern Saskatchewan, and in Northern Ontario eastward into Quebec. West of Regina and south of the Canadian Pacific Railway the conditions may be classed as pronounced drought, while in Algoma, Nipissing and Muskoka, and greater part of the Ottawa Valley, the total registered rainfall was only about 70 per cent. of the average of the previous seven years. The rainfall during September was above the average over British Columbia and to a marked extent on the Lower Mainland. It was also well above the average in the Western Provinces, except from the Qu'Appelle Valley to Prince Albert, where there was quite a deficiency. There was also a marked deficiency throughout Ontario, Quebec and the Maritime Provinces, except in the immediate vicinity of Quebec City, where there was an excess of 1·30 inches. The chief positive departures were Vancouver, 2·60 inches; Battleford, 2·70 inches Portage la Prairie, 2·60 inches; and the pronounced negative ones were Southampton, 1·50 inches; Toronto, 1·40 inches; Yarmouth, 1·80 inches; and Sydney, 2·00 inches.

## Temperatures for August and September, 1914

| Station | August Highest | August Lowest | September Highest | September Lowest |
|---|---|---|---|---|
| ***Yukon*** | | | | |
| Dawson | 74 | 30 | 70 | 12 |
| ***British Columbia*** | | | | |
| Atlin | 65 | 33 | 55 | 28 |
| Agassiz | 87 | 44 | 78 | 40 |
| Barkerville | 72 | 28 | 66 | 23 |
| Kamloops | 95 | 43 | 85 | 30 |
| New Westminster | 86 | 48 | 77 | 44 |
| Prince Rupert | 70 | 44 | 66 | 38 |
| Vancouver | 79 | 47 | 69 | 45 |
| Victoria | 82 | 46 | 71 | 44 |
| ***Western Provinces*** | | | | |
| Battleford | 90 | 35 | 80 | 30 |
| Broadview | | | | |
| Calgary | 96 | 36 | 82 | 30 |
| Carman | | | | |
| Edmonton | 85 | 41 | 79 | 31 |
| Medicine Hat | 102 | 37 | 89 | 35 |
| Minnedosa | 98 | 32 | 84 | 28 |
| Moose Jaw | 94 | 30 | 87 | 30 |
| Oakbank | 89 | 35 | 85 | 31 |
| Portage la Prairie | 95 | 35 | 88 | 31 |
| Prince Albert | 82 | 35 | 76 | 30 |
| Qu'Appelle | 88 | 32 | 87 | 29 |
| Regina | 92 | 31 | 89 | 29 |
| Swift Current | 100 | 32 | 82 | 28 |
| Winnipeg | 95 | 38 | 82 | 32 |
| ***Ontario*** | | | | |
| Agincourt | 94 | 45 | 88 | 34 |
| Aurora | 91 | 38 | 85 | 28 |
| Bancroft | 90 | 35 | 85 | 28 |
| Barrie | 93 | 43 | | |
| Beatrice | 89 | 36 | 84 | 27 |
| Birnam | 92 | 43 | 84 | 37 |
| Bloomfield | 89 | 44 | 83 | 36 |
| Brantford | 97 | 42 | 89 | 32 |
| Bruce Mines | | | | |
| Chatham | 94 | 46 | 91 | 38 |
| Clinton | 94 | 40 | 85 | 32 |
| Cottam | 94 | 45 | 90 | 32 |
| Gravenhurst | 95 | 35 | 87 | 26 |
| Guelph | 92 | 41 | 87 | 30 |
| Haliburton | 96 | 32 | 88 | 25 |
| Hamilton | | | | |
| Huntsville | 89 | 34 | 87 | 28 |
| Kenora | | | | |
| Kinmount | 92 | 34 | 86 | 25 |
| Kingston | 91 | 54 | 78 | 30 |
| Lakefield | 88 | 47 | | |
| London | 95 | 42 | 90 | 30 |
| Lucknow | 96 | 35 | 87 | 26 |
| Madoc | | | | |
| Midland | 96 | 48 | | |
| North Gower | 92 | 32 | 95 | 29 |
| Otonabee | | | | |
| Ottawa | 85 | 42 | 88 | 31 |
| Owen Sound | | | | |
| Paris | 90 | 44 | 90 | 34 |
| Parry Sound | 99 | 40 | 85 | 31 |
| Peterboro' | 92 | 40 | 87 | 32 |
| Port Arthur | 79 | 34 | 80 | 34 |
| Port Burwell | 83 | 52 | 78 | 36 |
| Port Dover | 93 | 47 | 87 | 34 |
| Port Stanley | 84 | 46 | 79 | 33 |
| Ronville | 91 | 36 | 84 | 28 |
| Sarnia | | | | |
| Southampton | 87 | 41 | 86 | 32 |
| Stonecliffe | 94 | 36 | 91 | 31 |
| Stony Creek | 90 | 44 | 89 | 35 |
| Stratford | | | | |
| Toronto | 92 | 48 | 78 | 36 |
| Uxbridge | 94 | 39 | 86 | 30 |
| Wallaceburg | 90 | 45 | 89 | 34 |
| Welland | 97 | 54 | 82 | 40 |
| White River | 86 | 22 | 81 | 20 |
| ***Quebec*** | | | | |
| Brome | 91 | 32 | 83 | 22 |
| Father Point | 88 | 42 | 76 | 30 |
| Montreal | 91 | 47 | 84 | 32 |
| Quebec | 90 | 41 | 83 | 27 |
| Sherbrooke | | | | |
| ***Maritime Provinces*** | | | | |
| Charlottetown | 85 | 47 | 82 | 36 |
| Chatham | 90 | 43 | 91 | 35 |
| Dalhousie | 82 | 43 | 89 | 35 |
| Fredericton | 85 | 39 | 90 | 30 |
| Halifax | 84 | 42 | 86 | 33 |
| Moncton | 84 | 37 | 87 | 26 |
| St. John | 75 | 46 | 77 | 34 |
| St. Stephen | 82 | 35 | 90 | 24 |
| Sussex | 80 | 40 | 88 | 32 |
| Sydney | 84 | 40 | 87 | 36 |
| Yarmouth | 73 | 44 | 74 | 36 |




RECORD OF MAGNETIC DISTURBANCES ON SEPTEMBER 27, 2
STATION OF




27, 28, 29, 1914, REGISTERED PHOTOGRAPHICALLY AT THE TORONTO (AGINCOURT)
N OF THE METEOROLOGICAL SERVICE

## MAGNETIC OBSERVATIONS

During the months of August and September the magnetic traces indicate much more disturbance in the magnetic field than for some time. The first and last weeks of August and the last week of September were particularly disturbed periods. The most pronounced feature of these magnetic storms, with the exception of that of September 27 and 28, was their duration rather than their amplitude or rapidity of change of direction or force. In the storm of September 27 and 28, however, both change of direction and force occurred rapidly and with great frequency, the commencement of disturbance in all three elements being at 14.55 o'clock on the 27th, and being marked by rapid increase of both Horizontal and Vertical Force and decrease of Westerly Declination.

On the 16th of August an Ad'e Vertical Force Magnet for photographic registration of changes in the Vertical Component of the Earth's Magnetic Field was added to the equipment of the Agincourt Observatory.

| Month | Mean of Month | Max. | Date | Min. | Date | Monthly Range | Amplitudes—Mean Daily: From hourly readings | Amplitudes—Mean Daily: From Means of Extremes |
|---|---|---|---|---|---|---|---|---|
| | | | | Declination W. | | | | |
| 1914 | ° ′ | ° ′ | | ° ′ | | ° ′ | ′ | ′ |
| Aug. | 6 25·6 | 6 46·1 | 2 | 5 57·6 | 28 | 0 48·5 | 13·2 | 19·3 |
| Sept. | 6 25·8 | 6 50·5 | 27 | 6 11·0 | 27 | 0 39·5 | 11·5 | 17·6 |
| | | | | Horizontal Force—C.G.S. Units | | | | |
| 1914 | | | | | | | | |
| Aug. | 0·16073 | 0·16120 | 17 | 0·15983 | 3 | 0·00137 | 0·00042 | 0·00064 |
| Sept. | 0·16063 | 0·16294 | 27 | 0·15954 | 28 | 0·00340 | 0·00039 | 0·00068 |
| | | | | Vertical Force.—C.G.S. Units. | | | | |
| 1914 | | | | | | | | |
| Aug. | | | | | | | | |
| Sept. | 0·58732 | 0·58869 | 27 | 0·58546 | 28 | 0·00223 | 0·00223 | 0·00011 |

Inclination

| Month | Mean Earth Inductor |
|---|---|
| 1914 | ° ′ |
| August | 74 41·1 |
| September | 74 41·9 |

## Earthquake Records by the Milne Seismograph

### TORONTO

R. F. Stupart, Director

P.T. = Preliminary Tremors. L.W. = Large Waves. A.C. = Air Currents.
Time is Greenwich Civil Mean Time, 0 or 24 h = midnight.

| No. | Date 1914 | | P. T. Comm. | L.W. Comm. | Max. | End | Max. Amp. | Durat. | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| | | | h m | h m | h m | h m | mm | h m | |
| 1372 | Aug. | 3 | 11 38·0 | 11 42·2 | 11 43·0 | 12 4·0 | 0·8 | 0 26·0 | Increase of move- |
| 1373 | " | 4 | 12 51·7? | 12 56·5 | | 13 22·5? | 0·05 | 0 30·8 | at 11h. 42m·2. |
| 1374 | " | 4 | 22 56·8? | 23 16·5 | 23 35·2<br>23 48·8 | 2 11·6? | 1·7<br>2·3 | 3 14·8 | Prolonged marked disturbance. |
| 1375 | " | 6 | 19 18·1 | 19 30·4 | 19 32·4 | 20 20·0 | 0·3 | 1 1·9 | |
| 1376 | " | 8 | 19 4·8 | | | 19 7·0 | 0·05 | 0 2·2 | |
| 1377 | " | 8 | 19 17·2 | 19 27·4 | 19 28·1 | 20 9·5 | 1·4 | 0 52·3 | Marked disturbance. |
| 1378 | " | 22 | 5 40·9 | 5 48·1 | 5 50·3 | 6 46·0 | 1·3 | 1 5·1 | Marked disturbance. |
| 1379 | " | 22 | 15 51·3? | 16 8·2 | 16 12·0 | 16 54·4 | 0·3 | 1 3·1 | |
| 1380 | " | 28 | 9 1·3 | 9 19·8<br>9 42·3 | | 9 50·0 | 0·05 | 0 48·7 | |
| 1381 | " | 28 | 18 0·0? | 18 6·3 | | 18 9·5 | 0·05 | 0 9·5 | |
| 1382 | Sept. | 4 | | 18 27·4 | | 18 42·4 | 0·1 | 0 5·0 | |
| 1383 | " | 10 | 10 10·5 | | | 10 14·5 | 0·05 | 0 4·0 | |
| 1384 | " | 11 | 12 5·2 | | | 12 34·1 | 0·05 | 0 28·9 | |
| 1385 | " | 12 | 16 44·8? | 16 46·6 | | 16 51·4 | 0·1 | 0 6·6 | |
| 1386 | " | 15 | | 0 43·9 | | 1 37·9 | 0·05 | 0 54·0 | Extended thickenings. |
| 1387 | " | 22 | | 23 58·3 | | 0 11·5 | 0·2 | 0 13·2 | Marked brief thick- |
| 1388 | " | 25 | 10 36·3? | 10 44·4 | | 10 56·1 | 0·05 | 0 19·8 | ening. |

Boom Period 17·7 seconds. 1 mm. = 0″·59.

No. on February 7th should read 1317, and July 21st 1371.

## VICTORIA, B. C.

F. N. DENISON, SUPERINTENDENT.

| No. | Date 1914 | P.T. Comm. | L.W. Comm. | Max. | End | Max. Amp. | Durat. | Remarks |
|---|---|---|---|---|---|---|---|---|
| | | h m | h m | h m | h m | mm. | h m | |
| 1382 | Aug. 4 | 23 4·5 | 23 16·3 | 23 31·3<br>23 35·3 | 1 20·5 | 2·5<br>5·7 | 2 31·0 | L.W. well defined. |
| 1383 | " 6 | 4 37·3 | 4 43·4 | | 5 12·7 | 0·2 | 0 35·4 | Phases doubtful. |
| 1384 | " 8 | | 19 20·2<br>19 22·3 | 19 26·1 | 19 49·6 | 1·3 | 0 29·4 | |
| 1385 | " 22 | | 5 28·9 | 5 29·7<br>5 31·7 | 5 51·3 | 1·3<br>2·0 | 0 22·4 | |
| 1386 | " 22 | 15 22·8 | 15 37·5 | 15 41·4 | 16 21·8 | 0·5 | 0 59·0 | |
| 1387 | " 24 | 7 12·7 | | | 7 16·6 | 0·1 | 0 3· 9 | |
| 1388 | " 28 | 9 5·3 | 9 15·6 | 9 18·6 | 9 46·3 | 0·4 | 0 41·0 | |
| 1389 | " 28 | 18 3·4 | 18 6·8 | | 18 26·2 | 0·2 | 0 22·8 | |
| 1390 | Sept. 2 | 21 7·5 | 21 14·0 | 21 15·0 | 21 25·5 | 0·2 | 0 18·0 | |
| 1391 | " 4 | 17 45·0 | 17 55·0 | 17 57·0 | 18 8·0 | 0·1 | 0 23·0 | |
| 1392 | " 10 | 10 6·2 | ? | 10 8·2? | 10 15·2 | 0·15 | 0 9·0 | |
| 1393 | " 11 | 12 5·4? | 12 27·4 | 12 30·4 | 12 51·4 | 0·1 | 0 46·0 | |
| 1394 | " 12 | 16 27·1 | | 16 39·1 | 16 33·6 | 0·15 | 0 6·5 | |
| 1395 | " 13 | 17 45·9 | 18 00·9 | 18 03·3 | 18 14·9 | 0·10 | 0 29·0 | |
| 1396 | " 15 | 0 15·1 | 0 30·6 | 0 33·1 | 0 51·1 | 0·2 | 0 36·0 | |
| 1397 | " 25 | 11 5·4? | 11 8·4 | 11 8·9 | 11 16·4 | 0·1 | 0 11·0 | |

Period 18 seconds. 1 mm. = 0″·54

J. Y.

## ASTRONOMICAL NOTES

STUDIES ON STAR MOTIONS.—Professor C. V. L. Charlier has published an essay in the *Meddelanden* of the Lund Observatory, in which he analyses the distribution of the proper motions in the "Preliminary General Catalogue" of Boss. He divides the sky into forty-eight squares, and finds the arrangement of proper motions, as regards direction and magnitude, in each of them. The combined result for the solar apex is:—

| | R.A. | | N. Dec. |
|---|---|---|---|
| Stars of 4th mag. to 5th mag. . . . | 267° | . . . | 35° |
| Stars of 5th mag. to 6th mag. . . . | 273° | . . . | 31° |

Assuming that the solar speed is twenty kilometres per second (after Campbell), he finds that the average parallax of the stars of magnitude five and a half is 0″·011, and their mean distance twenty-nine and a half siriometers (a term he uses to denote a million astronomical units). Kapteyn had found 0″·016, but his result was based on less complete data.

He then examines the rival theories of "Two Star Streams" versus "The Ellipsoidal Distribution of Velocities" (Schwarzschild), and favors the latter one, showing that it implies that "the mean velocity in the direction of the vertex is about double that at right angles to this direction." He also discusses the theory of Professor Turner that the stars are moving in elongated elliptical orbits about a centre. He finds that he can explain on this theory a certain want of symmetry in the velocity distributions, which would arise in case the sun were near the centre of motion, but not quite co-incident with it. He favors the theory without reaching a definite conclusion about it.

Professor Charlier reminds us that the small bodies of the solar system do not exhibit the equipartition of energy. However, their velocities are impressed on them by a single mighty mass—the sun — and their case is not quite analogous to that of isolated stars that are only under the influence of the combined attraction of the stellar universe.

One noteworthy feature of this important essay is that though it emanates from Sweden, it is written in English — and very good English, considering that the author is a foreigner. This compliment to our language is paid also by several other numbers of the Lund *Meddelanden.*— A. C. D. Crommelin, in *Knowledge*, No. 554.

The Late Sir David Gill. — Outsiders who have seen him at work at these congresses may have been under the impression that it was the geniality of his person, his infectious enthusiasm, and strong self-reliance which carried the day. But those who had followed matters closely would know how carefully he had studied every detail of the matter to be discussed, how long beforehand he had extensively corresponded with the most capable and most interested persons, and how he brought many of them together a few days before the date of the congress not only to arrange the programme for the proceedings, but also to discuss informally all the main points. All during the congress, too, he would bring the ablest men together for these informal discussions. In these, Gill would always play a prominent part; sometimes his impetuosity would make it far from easy for those opposed to his views to explain their standpoint. It might be some time before Gill would really give attention to what they had to say, but that moment having come, they could wish for no better listener, and if they succeeded in showing that their point of view was more nearly correct, no man would be quicker to recognize his error than Gill. No man could be long with him without feeling that here was a man to whom the real interest of science was paramount, a man who was always ready to sacrifice any pet plan of his own to the real interest of astronomy. A favorite expression of his, in giving up his opinion, would be: "The man who never makes a mistake is he who does nothing." I cannot help thinking that such personal qualities — his indomitable energy, his broad-mindedness, love of his work, kindness — his manliness in the best sense of the word, in short the charm of his strong personality, had almost as much to do with his achievements as his qualities as a scientist.

As a scientist Gill is best comparable in my opinion to F. G. W. Struve. The terms in which Argelander sums up his character-sketch of Struve in the *Vierteljahrsschrift der astronomischen Gesellschaft* (1, 52) are applicable almost word for word to Gill. And might not the following words be applied to Gill's *History of the Cape Observatory*: "There is inspiration to be found in nearly every page of it, for its author had the true genius and spirit of the practical astronomer — the love of refined and precise methods of observation and the inventive and engineering capacity:" As a matter of fact they were written *by* Gill *about* Struve. Even in the particulars of their careers there is the greatest parallelism.

In the annals of astronomy, Gill's name will take place with those of Bradley, Bessel and Struve. In many a human heart his image will last as long as life itself. — J. C. KAPTEYN, in *Astrophysical Journal* for September.

HARVARD COLLEGE OBSERVATORY.— *Bulletin*, No. 567.— A telegram received at this Observatory from Professor A. O. Leuschner, of Berkeley, California, gives the following elements of Campbell's Comet, computed by Miss Levy and Shane from observations on September 26, 27 and 29:—

ELEMENTS

| | | | |
|---|---|---|---|
| Time of perihelion passage | (T) | 1914, August 4·91 | G.M.T. |
| Perihelion minus node | ($\omega$) | 267° 48′ | |
| Longitude of node | (☊) | 0° 24′ | |
| Inclination | (i) | 77° 53′ | |
| Perihelion distance | (q) | 0·683 | |

*Bulletin* No. 568.—A telegram received at this Observatory from Professor A. O. Leuschner, of Berkeley, California, gives the following ephemeris of Campbell's Comet, computed by Miss Levy and Shane from observations on September 27, October 8 and 14.

EPHEMERIS

| G.M.T. | | R.A. | | | Dec. | | Light |
|---|---|---|---|---|---|---|---|
| | | h | m | s | ° | ′ | |
| 1914, October | 24·5 | 21 | 47 | 25 | + 1 | 06 | 0·23 |
| | 28·5 | 21 | 46 | 08 | 2 | 51 | |
| November | 1·5 | 21 | 45 | 48 | 4 | 19 | |
| | 5·5 | 21 | 46 | 10 | 5 | 34 | 0·06 |

EDWARD C. PICKERING, *Director*.

RADIATION FROM STARS.—In *Publications of the Astronomical Society of the Pacific*, No. 155, W. W. COBLENTZ, of the Lick Observatory, describes a new instrument termed a thermoelement which he says is perhaps a hundred times as sensitive as some of the radiometers used in previous attempts at the measurement of stellar radiation. With it quantitative measurements were made on stars down to the fifth magnitude and highly qualitative measurements were made on stars down to the seventh magnitude.

The instruments were used in conjunction with the Crossley Reflector at the Observatory.

The radiation from over one hundred celestial objects has been measured. No measurements were attempted on stars of less than the seventh magnitude, owing to the difficulty (lack of illumination) in projecting the star-image centrally upon the receiver. Furthermore, it was not apparent that much would be achieved in this preliminary work by so doing. The humidity during the summer nights on Mt. Hamilton falls below 10 per cent. and any slight variations in humidity have a marked effect upon the radiometric measurements, especially upon red stars, which have the property of emitting a great amount of infra-red radiation.

The total radiation received from a star is a function of its size, distance, temperature, and especially of its emissivity. The latter is a function of the kind and the physical condition of the material which forms the radiating layer of the stellar surface. To eliminate the effect of the size and the distance of a star upon the quality of the radiations received, measurements were made in which the stellar rays were passed through a layer of water $1^{cm}$ in thickness. The water absorbs all the infra-red rays of wave-lengths greater than $1{\cdot}4\ \mu$, and gives a rough comparison of the distribution of energy in the spectrum. The ratio of the galvanometer deflection caused by the stellar rays falling upon the thermo-element after passing through the water (*i. e.* those rays which are transmitted by the cell of water) to the deflection caused by all the stellar rays collected by the mirror and concentrated upon the thermo-element, gives the "*transmission.*" If the total radiation from a red star contains more infra-red rays than does the total radiation from a blue star, then the amount transmitted by the water cell will be less for the red than for the blue star.

From 50 to 60 per cent. of the light reflected from Venus, Saturn and Jupiter is transmitted by the water-cell. On the other hand, only 14 to 15 per cent. of the light of the Moon was transmitted by the water-cell. The explanation given is that the lunar surface becomes quite warm from exposure to the sun and in turn radiates heat waves, which are not transmitted by the absorption cell. The albedo of the moon being much less than that of the planets, it should become heated to a higher temperature and the transmission through the absorption cell should be the least, as observed.

The detailed data, which has been accumulated, will be published elsewhere as soon as possible.

A CONTRIBUTION to *Popular Astronomy*, No. 9., by Bernard Thomas, on "The Nearness of the Stars," concludes:—The considerations mentioned afford grounds for a belief that the universe of visible stars is smaller and more contracted than so often stated. Until we have more evidence to the contrary, we can assume that the extreme distance of the stars and nebulæ is not more, and probably less, than five hundred light years. That the less luminous stars far outnumber the brighter ones and are not at greater distance. That the sun is a star of more than average size and luminosity, although there are some which are giants in size and others with a brighter intrinsic surface. That the galaxy is within this belt, a cluster of clusters of small suns with slow motions and with larger suns amongst them.

THE ANNUAL REPORT of the British Astronomical Association for the year ending September 30th, 1914, shows the Association to be in a flourishing condition with thirteen observing sections. At the beginning of the year, the total membership was 972; during the year there have been elected 59 new members; resigned 23; deceased 18; excluded 24; leaving a total membership of 966. The bulk of these reside in England, whilst a number are distributed throughout Wales, Scotland, Ireland, Europe, North and South America, India, Japan, Australia and Africa.

LORD ROSSE'S TELESCOPE.—It is stated that the great 6-foot reflector at Birr Castle, Parsonstown, has been handed over to the Science Museum at South Kensington. So the active career of the mammoth telescope, which caused so much wonderment among men 70 years ago, has terminated in its becoming a museum curiosity! For years its practical utility had ceased. Its work had been accomplished. The great telescopes constructed in recent years had virtually rendered it obsolete.

Possibly it never quite fulfilled the hopes it encouraged, nor fully recompensed the ability and zeal of the man who conceived the idea of its construction and made it a reality; but it performed many important services, if it failed to reveal the satellites of Mars or the fifth satellite of Jupiter. The telescope earned for itself a most interesting history, and it will live in the story of astronomical progress.

Its powers were chiefly directed to the observation and discovery of nebulæ, and it was the first to reveal the spiral character of some of these objects. It was supposed that its great penetrating power had resolved the nebulæ, properly so called, into stars, but the spectroscope of Huggins showed this to be a misconception. The results obtained with the instrument were published in the *Trans. of the Royal Dublin Society* in 1879, and were entitled "Observations of Nebulæ and Clusters of Stars, made with the 6-foot and 3-foot Reflectors from 1848 to 1878." This valuable paper included 179 pages, many diagrams, and 6 plates. Other important contributions had been published from time to time. A series of valuable observations and drawings of Jupiter and his red spot were given in the *Monthly Notices* for 1873-4, xxxiv., p. 235.

The "passing" of the great Rosse telescope must give rise to a feeling of regret. But it will ever form an historical monument to the genius of the nobleman who designed and perfected its construction. It gave thrills to astronomical enthusiasts, and its possibilities aroused the interested attention of the public. The valuable work it performed justified its erection if it failed, like Herschel's 4-foot, in contributing many sensational items to astronomical progress.—W. F. Denning, in *The Observatory*, No. 478.

The Australian Meeting of the British Association.—The opening address to the Section of Mathematics and Physics was delivered by Professor F. T. Trouton, M.A., Sc.D., F.R.S., President of the Section. After referring sympathetically to the loss which science has suffered by the death of Sir Robert Ball, Professor Poynting, Sir David Gill and Mr. Sutherland, he congratulated the Universities of Australia and New Zealand on the large number of their past students who have enriched science by research, especially in subjects connected with radio-activity. The work of Rutherford and others had shown that the stores of energy in the atom were unlocked, and it became a question whether the energy involved in our motion through the luminiferous ether could not be tapped, "despite the ingenious theories of relativity which have been put forward to explain matters away." The readiness with which the doctrine of "Relativity" had been accepted was an exaggerated example of the catholicity of present-day science.—In *Knowledge*, No. 555.

J. R. C.

## NOTES AND QUERIES

**Communications are Invited, Especially from Amatuers. The Editor will try to Secure Answers to Queries.**

### Query

At the spring equinox, which occurs on March 21, the sun is on the equator and, therefore, the day and the night are of equal length. However, on referring to the newspapers at that time or to our Handbook, page 12, I find that in latitude 44° the sun rises at 6·01 and sets at 6·13, giving $12^h\ 12^m$ of day and $11^h\ 48^m$ of night; or the day is $24^m$ longer than the night. How is this?—J. C., (Toronto.)

### Answer

An explanation of this discrepancy is to be found in the first paragraph of page 9 of the Handbook, where it is stated that the times given in the tables are for the rising and the setting of *the upper limb, corrected for refraction*. If the sun were a luminous point, without any apparent diameter, and the earth were devoid of atmosphere, then at a place having a sea horizon the day and the night at the equinox would be equal. Of the difference between their lengths, about one-third is due to the sun's size, the rest to refraction by the atmosphere. For a fuller explanation of refraction refer to a text-book on astronomy.

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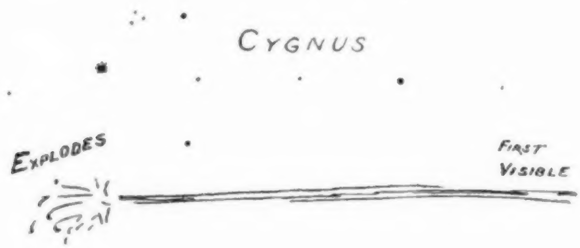
## OBSERVATIONS IN BERMUDA

From Colonel W. R. Winter, of Bermuda, the Editor has received an interesting letter, dated October 14, from which he takes the liberty of quoting.

"The weather here for six weeks has been against observations. I believe I had a glimpse of Delavan's Comet at the end of September through the clouds. It appeared like this. (Sketch added showing its appearance and position near the 'Big Dipper'). Short tail, with well-rounded nucleus and envelope.

There has been little to note this year. The last week in June was remarkable for a fine display of large meteors — sometimes two or three a night, and they were heard in the daytime. The radiant point was in the neighborhood of Aquila and direction generally westward. The largest observed was on 26th June at 7.20 p.m. Its course was as under (see figure) and had




PATH OF LARGE METEOR SEEN IN BERMUDA

JUNE 20, 1914.

it been dark it would have been a splendid sight. The sound of the explosion, which was very loud, reached us in 8·05 minutes (about double the average). It burst into a fine bunch of red, yellow and greenish pieces, which travelled on and gave out sparks for about two or three seconds.

At 5.23 p.m., 23rd September, a fine circular rainbow-halo was observed round the sun. The inner circle, rainbow-coloured, had a diameter of about 40°, the outer circle was a pearly gray halo about 60° in diameter. This was followed by a very heavy dew."

## ANOTHER ADDITION TO JUPITER'S FAMILY

The first-fruit of the invention of the telescope was the discovery by Galileo in 1610 of the first four satellites of Jupiter, bodies which ever since have excited the keen interest both of the professional and the amateur astronomer. The fifth satellite was not revealed until 1892, nearly three centuries later, when Barnard detected it with the then recently installed Lick refractor. In the winter of 1904-05, by means of photographs taken with the Crossley reflector, of the same observatory, Perrine discovered satellites numbered six and seven. These three bodies are all very small, the stellar magnitudes being approximately 13, 14, 16, respectively. Then in 1908, Melotte, of Greenwich, by photography discovered an eighth satellite, of about the 17th magnitude; and now the Lick Observatory has again distinguished itself by adding a ninth member to the family.

An account of the discovery is given in the *Publications* of the A. S. P., and in *Popular Astonomy* by Mr. Seth B. Nicholson. On July 21, while volunteer assistant at the Lick Observatory, Mr. Nicholson photographed the eighth satellite with the Crossley reflector, and on the following night a second plate was secured. On comparing the two plates a new image was found slightly east and south of the eighth satellite. From the distinctness of the images on the plates, which had received an exposure of two hours, the new body was judged to be of nearly the nineteenth magnitude, that is, a magnitude or more fainter than number eight. On July 23 and 24 it was again photographed, and then Acting Director Tucker made telegraphic announcement of the discovery of the unidentified object. The body was followed further during July and August until sufficient observations had been secured to prove that it was a new satellite. Its motion is retrograde and its period about three years, and hence its mean distance is about 18,900,000 miles.

It is worth noticing that satellite number eight, which has a mean distance of about 15,600,000 miles, as also the ninth satellite of Saturn, which has a mean distance of about 8,000,000 miles, all move retrograde. Of all the satellites in the solar system these revolve at the greatest distance from their primaries, which fact must have some significance in the theories of evolution of the system.

As the precise date of an astronomical discovery is always of interest I may be pardoned for quoting from an old letter which I received from Professor Perrine, to whom I had written regarding the sixth and seventh satellites. The letter is dated February 13, 1907, and I take the liberty of quoting the following paragraph: —

"As to the *dates* of discovery I am not quite certain in both cases. I think I detected VI. on either December 9 or 10, 1904; VII. I found on January 5, 1905. These dates are the dates on which I detected the *images*. Their character was not made certain until the dates of announcement."

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## DELAVAN'S COMET

This comet has been well observed by amateurs during September and October as it has been easily visible to the naked eye. It was discovered by P. T. Delavan, of the La Plata Observatory, Argentine Republic, on December 17, 1913, while searching with the eight-inch Zeiss comet-seeker of that institution. It was very faint, scarcely brighter than the eleventh magnitude. The elements of the orbit, computed from observations on December 17 and 30, 1913, and January 8, 1914, gave October 30, 1914, as the time of passing perihelion, but later computations gave October 26 as the date. Very seldom has a comet been discovered so long before perihelion passage.

We had hoped to reproduce in the present number of the JOURNAL a photograph of the comet taken by Mr. Motherwell, of the Dominion Observatory, with the photographic outfit described on page 305; but in the evening the view of the comet was obstructed by the main building of the Observatory and in the morning the city lights so illuminated the sky where it was that satisfactory negatives could not be obtained.

C. A. C.